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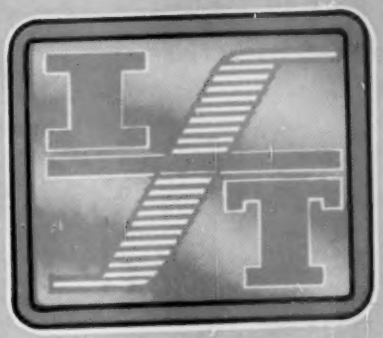

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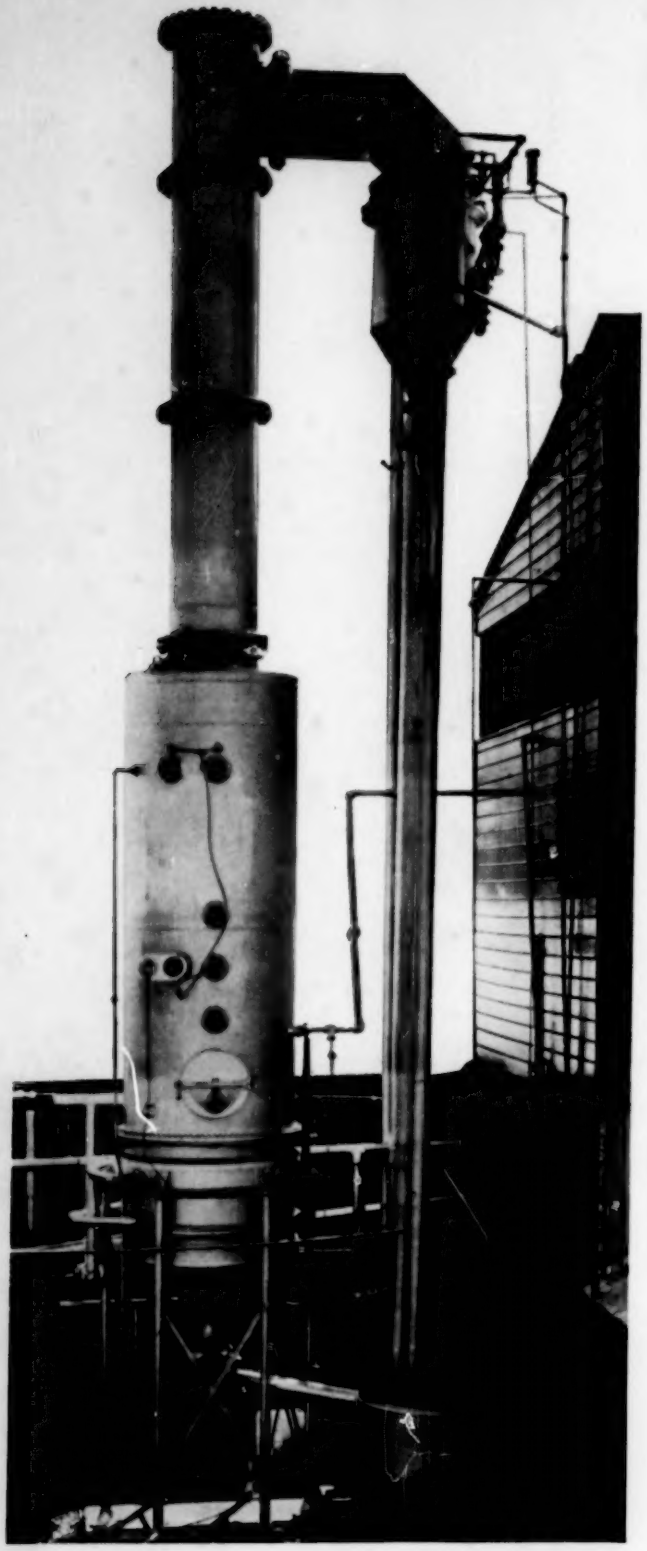

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Food Technology Curricula

Some Viewpoints of One in Industry

FRANK L. GUNDERSON

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This is the seventh of a series of articles concerned with basic ideas relating to the curricula of our educational institutions in the field of food technology, and to the views of food technologists in industry. The six previous articles describe the curricula at some of our leading educational institutions and modern trends in technological education. The discussion below presents some of the viewpoints of one in industry who asks that the point be emphasized that the views are his own personal ones and that they may or may not coincide with those of his employer or with the food industry in general.

(Received for publication, December 20, 1950)

The interest of food industries in the training of food technologists is already very lively. Many key and lesser positions in industry are occupied by men and women trained in the principal fields which form the basis of food technology. Moreover, in recent years an increasing number are receiving academic training in curricula formally planned and designated as food technology. Following their training, these people are usually employed in production, research and development, processing, packaging, transportation, distribution, or food utilization.

This article is but one in a series in which all of the prior reports are by men affiliated with educational institutions: Rushton and Parker *(12)*, Wiegand *(14)*, Proctor *(10)*, Fellers, Levine and Anderson *(5)*, and Heald *(8)*. In addition one should include Dr. Wiegand's excellent report of 1945 *(13)*. Burton's *(1)* survey of food manufacturers' opinions clearly revealed ten years ago the importance of "the human relations angle" of training and one can well question whether current curricula are adequate in those respects. Cruess *(3)*, at the same meeting expressed his view that new graduates in food technology usually have satisfactory grasp of theory and principle but that they are often unable to write concise, accurate and intelligible reports. I agree with both Burton and Cruess. Their reports have so thoroughly covered the field it is difficult to make important additions. If only a few pertinent points from the viewpoint of one in industry can here be brought into focus, then perhaps this further effort will have been worth while.

For a resume of the early discussions of food technology one should refer to the record of the 1938 conference *(6)*. The late Thomas M. Rector *(11)* was apparently the first to use the designation "food technology." He was so cited by Prescott *(9)* to whom many of us refer affectionately as the Dean of Food Technology. The Constitution of the Institute of Food Technologists *(2)* describes food technology as essentially " . . . the application of science and engineering to the production, processing, baking, distribution, preparation, and utilization of foods." Whereas one might at first glance regard the definition as covering most every phase of the food industry, that is far from the real case. To these phases one must add finance, procurement, advertising, sales and sales service, taxes, insurance, law, labor relations, public relations, civic responsibilities, and perhaps even others. Any man or woman who aspires to heavy responsibilities in food technology needs not only special training in the various parts of the technology itself and the basic science on which the technology is founded, but he needs also to be at least moderately conversant with the non-technological aspects of the business. This does not imply that he must be an expert in sales and finance. Food technologists, however, will serve better in their phase of the industry if they have substantial understanding and sympathy with the other aspects beyond their own primary responsibilities.

On completion of their courses, whether at the end of four or more years of academic training, most young men start their services down in the ranks. Both employee and employer need opportunity to become mutually oriented to the new affiliation. A young graduate applicant usually states that he would like a "position with an excellent opportunity for advancement." That is a commendable aspiration but all too often the applicant fails to appreciate that he himself will have great influence on those "opportunities." If he is capable, sincere, industrious, cooperative, personable, and adaptable on a moment's notice to the unexpected, then he will surely make his own opportunities for advancement. While there are a few exceptions, most business leaders are anxious to delegate increasing responsibilities commensurate with the employee's ability to handle them.

Frequently, employers find the recent graduate gifted not only in technology but in group leadership, in creative research, in business management, in sales promotion or service, or in some other phase of the broad operation. Most business executives are quick to recognize outstanding ability and make new assignments accordingly. Too often, however, the employer finds to his sorrow that the university graduate in technology has been so highly "pointed" to the sciences that he lacks balance and perspective. Competence in tech-

nology may be enough to justify continuing employment of a technician, as for example to make routine analyses. That alone, however, is not an adequate base for a college graduate who should be sufficiently broad as well as deep, to comprehend not only the shape of the parts (of business) but also how they fit together to operate as a unit.

Thus, it is herewith suggested that the greatest opportunity for improvement of food technology curricula lies not in the technological courses themselves but rather in elimination of some technical courses, in abbreviation of others, in order that more training can be accomplished in subjects outside the physical sciences and engineering. To me, it appears the steps being taken in this direction are too short and too slow.

We recognize that the "laboratory section" and sometimes, too, the "quiz-section" classes in the physical sciences in large universities (such as those which have food technology curricula) are taught by post-graduate students who themselves may have little ability or interest in teaching. Sometimes they hold the "instructorship" only to earn subsistence or because there are not enough qualified professors on the staff to go around. Thus students' time in the laboratory is often wasted. Time-consuming laboratory courses may crowd out needed courses which can be given more compactly and with greater opportunity for genuine discussion between students and learned teachers. Another factor which aggravates the situation, too, is the faculty recognition which is given to research over that given to teaching proficiency.

Increased attention should be directed toward development of the personality of college and university graduates. Pleasing personal characteristics are often as important (if not more so) in the selection and retention of associates as is the strictly professional ability of the person. At least, an abundance of the latter seldom compensates for lack of the former. On an earlier occasion it was my privilege to call attention *(7)* to desirable personal characteristics of research and development personnel. Those characteristics are equally applicable to food technologists in general and to non-technological workers. Indeed, for foundation and confirmation in this respect I drew heavily on a statement by the Engineers' Council *(4)*.

Here are some of the main groups of characteristics which the Engineers' Council commend to us and which I believe should be assured so far as possible in university students as prerequisites to their graduation. They should be: professionally energetic or dynamic, dependable, organizationally acceptable, emotionally acceptable, physically acceptable, and intelligently or mentally endowed. Practically all trained technologists enter into work with other people. Contrasting with the fact that the literary or musical composer can perform successfully as a rugged individualist without teamwork, a strictly "lone-wolf position" in food technology is rare.

The Engineers' Council states under the caption "organizationally acceptable" that engineers should be self-possessed rather than embarrassed; dignified rather than crude; thoughtful rather than exhuberant; likeable rather than repugnant; considerate rather than selfish; and cooperative rather than antagonistic. One could go on citing other characteristics, all of which are reasonable and practical requirements in the individuals with whom we like to work over prolonged periods through success as well as adversity. The opportunity for improvement of the curricula to bring out the best in individual character is greater in these respects than with respect to the strictly technological subjects, apparently because disproportionately greater attention has been focused on the technological features.

Those of us who have been trained primarily in sciences and technology and who have had administrative responsibilities have observed what were the strong and what the weak points that either aided or impaired the effectiveness of ourselves and our technical associates. In a few instances there was insufficient technological ability of the requisite type. In a larger number of cases, however, the shortcomings were primarily in the realm of personal characteristics. If the technologist was improperly fitted to his work and was highly personable, another assignment was usually forthcoming. If the person was not well liked by his associates, the tenure was limited.

Although no survey has been made to disclose the statistics, it is believed that the greatest percentage of the food technology graduates leave universities upon completion of a four-year course (with B.S. or comparable degree), a much smaller number after the five-year course (with M.S. degree), and a very small percentage with seven or more years of training leading to the D.Sc. or Ph.D. degree. One does not need dwell long on the unfortunate fact that the difficulties of including in the curriculum all the desirable courses is most acute with the majority of the students who of necessity or of choice leave the academic environment after only four or five years.

It is submitted that an improvement would be effected if the curricula were so designed to assure that all graduates in food technology have more training in the humanities, in the social sciences, and in the methods and importance of the written and spoken word as well as in the arts which lead to desirable personal characteristics.

One must look to more effective use of the food technology student's time if he is to have the opportunity to establish his broad foundation to fulfill in best degree the opportunities of citizenship, pleasant and effective social relationships, and high technological achievements. It is suggested that the amount of time spent in strictly laboratory classes of such subjects as chemistry, biology, and perhaps engineering, should be reduced. No doubt this decrease of laboratory training might lessen the student's skill as a technician, but the broader education he would thus have opportunity to acquire would more than outweigh the loss in technique of laboratory work. An increasing proportion of non-technological courses is recommended for food technologists to ensure broader capacity together with finer personality and character.

As this article goes to press some of us have been consulted here by a fellow scientist from England who is making a studious investigation pointing toward

establishment of a National College of Food Technology in London in 1951. As described in a news note *(15)* the Ministry of Education, the Ministry of Food, and representatives of the various sections of the food industry are planning jointly for this college which will provide the food industry with training at a high level. "The college will operate on the principle that a sound basis for advanced technology is a good foundation of science coupled with industrial experience and it will draw its students from industry at an age beyond that of the usual college student; 23 or more years of age has been mentioned as the standard." This development will be watched with interest by educators and food technologists in this country.

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Progress on Special Rations[a]

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In evaluating progress on special rations for the Armed Forces, two major factors should be considered. First: of the special rations used in World War II, only one would be satisfactory if we should become engaged in another war. And second: we have made progress in developing special rations to meet our anticipated needs.

Rations which were satisfactory in one war are not necessarily satisfactory in the next. For example, the rations used in World War I were designed for a static type of trench warfare, while those for World War II were designed for a dynamic, mobile type of warfare. Today's rations must be designed for even greater mobility, and even greater versatility. Outmoded rations can be eaten. But by the same token, outmoded rifles can be fired, and antique vehicles can be driven. Man can fight more effectively with rations designed specifically for today's war, not yesterday's.

The best known rations of the late war were the B ration, the C, the K, the "10-in-1," and the D bar.

The B ration, as we knew it in World War II, is essentially unchanged and is still suitable for feeding groups of men in the rear areas where kitchen equipment and kitchen personnel are available. Some improvements have been made. But the ration as a whole, consisting of non-perishables for kitchen preparation, is largely what it was five years ago.

The Combat, or C ration, on the other hand, has been measurably changed and improved. This ration was issued to the individual soldier in combat zones when there were no kitchens at hand. One of its major faults was the difficulty in issuing the 6-can ration to individual troops in darkness. Since the cans containing meat and those containing biscuits were of the same size, the soldier never knew until too late whether he was getting biscuits or meat. Today the "Ration, Individual, Combat" is issued in an individual carton. It is the carton, not the separate cans, that is given the soldier, and he is thereby assured food of the quantity and variety intended for him. Disliked items have been eliminated from the ration, and more desirable ones have been added. The C ration now contains canned fruit, cigarettes, and accessory items, as well as biscuits and a variety of meat products.

The K ration of World War II days was a highly compact ration in three packages, one for each meal. It

[a] Presented at the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 25, 1950.

was issued for men in assault, on the march, or in flight. Although it performed a valiant service in the war, the K ration has become a post-war casualty, giving way to newer concepts of military feeding. In all justice to the K ration, however, more than one packet was needed to replace it. The "Food Packet, Individual, Assault," is one of these. When men are in the assault phase of combat, they require food to tide them over until supply lines have been re-established. The Assault Packet has been developed to meet that need. It weighs about one pound, can easily be carried wherever the soldier goes, and its meant to be eaten when the soldier is under great stress and may have very little time or desire for food. It is not a ration; it is not a meal; it is food for men in assault.

Another packet that was unknown in World War II is the "Food Packet, Individual, Combat, Type In-Flight." Prior to the development of this item, air crewmen and airborne troops were given K rations, C rations, chocolate bars, sandwiches, or packed lunches for their longer missions. But the ever-increasing emphasis on air operations and the development of aircraft capable of conducting missions of longer range made it necessary to develop a specially designed food packet for men in flight. The "Food Packet, Individual, Combat, Type In-Flight," is the current answer to that need.

The last war required no extensive battle operations in extremely cold areas such as the Arctic or the upper reaches of Canada. The few troops in the northern areas consisted of organizations equipped to serve meals piping hot in indoor mess halls. However, future emergencies may entail actual combat operations at temperatures of 40 to 80 degree below zero. Under those conditions men will need rations to be eaten far from their kitchens. None of the individual rations will do for extremely cold climates because of the nature of the components. The fruits of the "Individual Combat Ration" would become a mass of ice. The meat components would be frozen chunks, and the individual soldier would have to stop and build a fire to thaw his foods before eating them. Should it be necessary to engage a future enemy in areas of extreme cold, the individual combat soldier will have a ration he can eat in the field in sub-zero weather. It is the "Ration, Individual, Trail, Frigid."

Probably the best liked special ration of the late war was the "10-in-1" which provided enough food for ten men for one day. It was designed for groups of approximately ten men without a kitchen, but probably with some sort of heating equipment. Since the ration was extremely popular, it was decided to make it available to more men than before. Its bulky size and weight were cut in half, and the "10-in-1" has now become the "Ration, Small Detachment, 5-in-1." It has enough food for five men for one day and is intended for tank crews, wire parties, gun crews, or similar groups separated from their kitchens.

One of the rations of the late war whose passing few will regret is the old D ration. The D was a chocolate bar with a very high caloric content and was intended as an emergency ration when troops were stranded or cut off from supply. However, the soldiers who ate it were not well disposed to the D ration. They claimed it was much too hard and far too rich. Its successor is not yet decided upon, but several candidates are being considered. At the present time an experimental survival ration for use in cold weather areas is being tested. Another is being developed for use in the Tropics. A survival ration for use in lifeboats is in process of development as well. The ultimate aim is to develop an all-purpose ration for survival conditions.

Regardless of progress made in the design and redesign of special rations, no ration is better than its component foods. Redesign is of little value if the foods do not provide a diet that is nutritionally adequate, if the foods spoil during shipment or storage, if they are not liked by the troops who get them, or if they cannot be easily carried, opened, and prepared with the simplest equipment, and eaten hot or cold wherever the soldier may be.

Significant advances in the quality of ration commodities have been made through painstaking review of each subsistence specification for the Armed Forces. Many have been revised and strengthened by inclusion of more precise descriptions of the products needed. In preparing specifications during the war it was often necessary to resort to hasty measures. As a result, manufacturers and food processors had limited information on the kind of products the Armed Forces needed. The vague phrase, "according to good commercial practice," found its way into specifications whenever the need for a product was so urgent that no time was available to obtain exact definitions. Another such phrase was "the product shall be of good texture." Frequently, however, no definition of good texture was included. The fact that our rations were as satisfactory as they proved to be is a tribute to the integrity and conscientiousness of American industry which supplied foods and containers to the Armed Forces during that period.

I will not imply that all of the Armed Forces specifications have been made infallible and foolproof. The expression, "according to good commercial practice," is still used. But specific requirements have been substituted for the general ones wherever it has been possible.

Every effort has been made to apply recent advances in food science and technology to each procurement of subsistence items for the Armed Forces. Notable among the improved products is powdered eggs. In World War II the G. I. was, to understate the case, not particularly happy about his powdered eggs. That may have been because off-flavors had developed in storage. Specifications now call for a powdered egg which is far more stable during storage than the wartime product. The wartime eggs were stable for six months at room temperature. The new product holds up for 18 months. The wartime eggs stood up for nine months at 40° F. The improved product is stable for 36 months.

The supply of beverage milk to troops stationed overseas has always been a difficult problem. But in the Far East, occupation troops are now receiving recombined milk bottled in the familiar waxed paper containers.

Reports from that area indicate that the milk is highly acceptable, and that the recombining plants are operating above planned capacity to meet demands. Recombined milk, in its present stage of development, is not designed for the packaged operational rations. Nevertheless, it represents a significant advance in supplying milk to troops located in areas where plants can be established and distribution of the finished product conveniently made.

During the war the Armed Forces were able to save millions of dollars in shipping weight and shipping space by buying 3-way frozen boneless beef instead of carcass beef. Although the 3-way beef was highly successful, it has recently been improved. The product is now a 4-way boneless beef with more of the fat removed. The new product will result in additional savings in shipping space and weight and in transportation costs. It is impossible to estimate the savings involved, but they are sizeable. The 4-way boneless beef will make the cook's job easier by insuring that the different cuts of meat are more easily identified by inexperienced kitchen personnel and will also improve acceptability. These are only a few of the improvements the Armed Forces special rations have experienced since the war. There are many others of general interest. For example, for coffee drinkers who like their coffee with cream or milk there has been added to several of the special rations a sweetened, condensed, dehydrated milk. First reports from the field indicate that the dried milk has been very well receeived. Some of the rations now have soluble tea in addition to soluble coffee.

Twelve unpopular canned meat items have been eliminated from the operational rations and a few of greater acceptability have been added. A dehydrated meat bar has been developed for the "Ration, Trail, Frigid." The meat bar needs no heating and is designed for troops in the field in cold weather areas.

There has been developed a quickly rehydratable precooked pea soup. The dehydrated soup powder is put in hot water, stirred for only a few seconds, and makes a highly acceptable soup that can be easily prepared in the field with the most rudimentary heating facilities. This soup is not yet in the rations but will probably be included in the near future.

Canned bread has also been developed for inclusion in the rations in the future. Storage tests at the Institute show that it has remained acceptable for as long as 24 months. Many Armed Forces units in overseas areas have no bakery in the vicinity to provide fresh bread. For these units there is under development a foil-wrapped bread which has remained acceptable for more than 100 days under laboratory storage conditions.

Some of these advances may appear impressive, others may seem of lesser importance, but each is a step toward improvement. Armed Forces rations are far from having reached a state of perfection. Many difficult problems remain and most of them can be solved only through the combined efforts of the Armed Forces and representatives of industry, universities, and other organizations able to contribute to the development of military rations. Let me state briefly a few of the current problems.

The canned meat items in the special rations need to be improved. They have a canned meat flavor and texture which detract from their acceptability. More canned meat items sufficiently different to offer variety are needed.

In cereal products newly developed, more stable premixed cereals and data on quality standards are needed so that stability can be improved. The Quartermaster Corps would also like to be able to buy flour dehydrated to a moisture level of two percent in order to improve the storage life of prepared cake mixes.

With respect to dairy products, good stable spreads for bread, a milk fat that will hold up for extended periods without refrigeration, and an evaporated milk that does not require turning in storage are needed. Above all, there is a requirement for a good dried milk product that can be easily made into a glass of beverage milk by the soldier in the field.

Better dehydrated fruits and vegetables should be developed, products that taste better and last longer in storage. We need stable precooked dehydrated soups that can be prepared almost instantly by adding hot water. Pea soup with the desired qualities has been produced on a laboratory scale, but additional kinds are needed. We also need an acceptable dehydrated orange juice which will remain stable for six months at 100° F.

The soluble coffees currently available do not resemble freshly brewed coffee in aroma and flavor. We need a coffee product that does. We are also looking for an imitation black pepper which can be used in an emergency if our foreign sources of genuine black pepper are cut off.

The problems are not limited to food products alone. We must have containers and container materials that will protect rations and ration items at temperatures as low as —80° F. and as high as 160° F. Watervapor-resistant barrier materials are needed to protect the contents of the container in the same temperature range.

These are only a few of the problems we are now facing. However, the fact that these problems are still unsolved does not mean that our rations are unsatisfactory. On the contrary, never in the history of the United States Armed Forces has this country been able to produce rations equal to those which can be supplied today.

The Quartermaster Food and Container Institute has not achieved this progress through its own efforts alone. Industry has cooperated fully in making the advances in rations possible. Food and container experts in industry, universities, and Government laboratories throughout the United States have provided advice, plant facilities, laboratories, and personnel to assist the Armed Forces' research and development program. Much of the progress made would have been impossible without the cooperation of these collaborators. The progress that has been made since the close of the war is extremely heartening. But we are still faced with the challenge of our unsolved problems. It is the task of all of us to make certain that our troops will have the advantage over any potential enemy, not only in weapons, but in food as well.

Role of Glucose in the Storage Deterioration of Whole Egg Powder I. Removal of Glucose From Whole Egg Melange by Yeast Fermentation Before Drying[a]

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(Received for publication, June 17, 1950)

This paper describes factors requisite to the preparation of an organoleptically acceptable glucose-free whole egg powder by resting-cell yeast fermentation.

British investigators showed that the removal of glucose from whole egg melange by a yeast fermentation before drying largely prevented the degradative changes associated with the protein constituents which occur during the storage of whole egg powders *(2, 9)*. However, the fermentation process employed was empirical and did not permit evaluation of the effect of glucose removal on flavor stability due to the foreign flavors introduced by the process. Unfortunately, other considerations discouraged further attention to glucose as a major participant in off-flavor development. Thus subsequent research by other workers during World War II suggested that the off-flavor development in stored whole egg powder occurred principally in the lipid constituents, in particular the phospholipids *(3, 6)*. Storage of separate dried fractions of whole egg led these workers to conclude also that the dried egg white constituents, which contain most of the glucose (whole egg contains approximately 1.2 percent of free glucose on a moisture-free basis; about 80 percent of the total occurs in the white and 20 percent in the yolk), were not an integral factor in the development of off-flavors. Of course, the fermentation of egg white as a step in the preparation of stable commercial albumen is an old commercial practice. Stewart and Kline *(18)* demonstrated that one of the necessary accomplishments of this fermentation was the removal of glucose. However, the main consideration with albumen is the prevention of the glucose-protein interaction which otherwise results in browning and loss in functional value *(2, 13, 14)*, and the stability problem is therefore not necessarily related to the flavor stability problem for whole egg powder, a much more complex substance. Recent studies in this Laboratory have revealed, however, that glucose plays a major role in the development of off-flavors in whole egg powder stored at moderate to elevated temperatures.

A resting-cell yeast fermentation procedure has been refined to the point where organoleptic evaluation of the glucose-free powders is readily permissible and it is the purpose of the present paper to describe the derivation of procedures used for the preparation of these powders. The effect of several factors on the fermentation process and on the quality of the resulting dried whole egg is described. These include: pH, temperature, yeast concentration, and particular yeast organism used.

Subsequent papers in this series will be concerned with the gross effects of glucose removal on flavor, functional and chemical stability of whole egg powder and with the evidence for a previously unrecognized deteriorative reaction involving the interaction of glucose and the phospholipid, cephalin. This latter reaction appears to be responsible for the major part of the lipid degradation occurring during the storage of whole egg powder at moderate to elevated temperatures.

Both *Torulopsis monosa* and *Saccharomyces cerevisiae* were used in the preparation of acceptable glucose-free whole egg powders for storage evaluation purposes and hence the description of factors affecting the process are largely concerned with these two yeasts. The use of *T. monosa* originated in other work proceeding concomitantly at this Laboratory, in which analytical use was made of the restricted fermentative ability of this organism which ferments only glucose, fructose, and mannose.

The fermentation of egg white as usually carried out commercially is a long-time process (one to four days) and is actually dependent upon the growth of the microorganisms *(5, 7, 10, 17, 19, 20)*. This growth method for removing the glucose, as compared to a resting-cell type fermentation, offers the single advantage that separate culture and harvest of the cells is not required. However, the removal of glucose from whole egg melange by a natural fermentation process or by the use of small inocula of pure cultures does not seem feasible, since the variety of substrates and growth-promoting substances in whole egg would certainly result in disagreeable odors and flavors emanating from the development of lipolytic and proteolytic flora. For this reason, a short-time (2 to 3 hours) resting-cell fermentation with yeast has been used in this Laboratory for the preparation of glucose-free whole egg powders. This method was explored by Ayres and Stewart *(1)*, who fermented the glucose in egg white in 2 hours using 0.5 percent of dry yeast *(S. cerevisiae)* and by Hawthorne and Brooks *(9)*, who used 1 percent wet weight of *Saccharomyces apiculatus* to remove the glucose from both whole egg and egg white in 3 hours at 37° C. In both cases, the product was reported to be either "very yeasty" or the foreign off-flavor was objectionable and conditions required to produce an acceptable product were not investigated. Josh, Harriman and Hopkins in a patent *(11)* issued since the work to be reported here was largely completed, claim, but offer no supporting data, that excessive yeastiness and off-

[a] Presented before the Tenth Annual Meeting of the I. F. T., Chicago, Ill., May, 1950, under the title "Egg Powder of Greatly Improved Stability."

[b] Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture. Report of a study made under the Research and Marketing Act of 1946.

flavor can be avoided while removing glucose from egg melange with bakers' yeast.[e]

MATERIALS AND METHODS

Preparation of the various yeast cell suspensions used in the fermentation process was as follows: The growth on a fresh 24 to 48 hour slant (composition same as growth medium plus 1.5 percent agar) was suspended in 6 ml. sterile water and used to inoculate six 500-ml. wide-mouth Erlenmeyer flasks containing 200 ml. each of culture medium. The medium contained 2 percent glucose, 1 percent yeast extract, and 0.5 percent tryptone and was adjusted to pH 6. The flasks were shaken mechanically, to provide aeration, for 24 hours at room temperature, after which the cells were centrifuged out, washed twice with 1 percent NaCl and then made up to a convenient volume. About 10 to 12 g. of yeast (dry basis) was usually obtained by this procedure from 12 flasks containing 2400 ml. of medium. The dry weight of yeast per ml. of the suspension was determined (vacuum oven at 55° C., 0.1 mm. Hg, 5 hours) and the amount of yeast used in subsequent fermentations is expressed in terms of this dry weight. The suspensions were used within two weeks of their preparation and were kept at 2° C. when not in use.

Some of the studies on factors affecting the fermentation were carried out manometrically. For such tests, 2.0 ml. of whole egg melange was placed in the center of a Warburg vessel and the yeast suspension (0.3 ml. or less) dumped from the side arm after flushing out the air with nitrogen. The time required for the fermentation was determined from the plot of carbon dioxide evolution *vs.* time as illustrated in Figure 1,

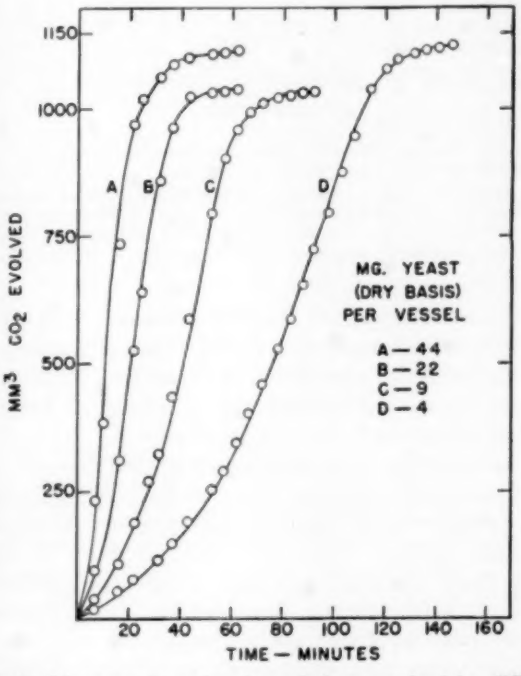

FIG. 1. Manometric estimation of time required by different amounts of *T. monosa* to ferment glucose in whole egg melange. (2.0 ml. egg, pH 7.4, 30° C., N_2 atmosphere.)

and was taken as the time required to reduce the rate of carbon dioxide evolution to that of the apparent endogenous value.

Vat-type fermentations were also carried out in determining the effect of yeast concentration and the relative efficacies of different yeasts. These consisted of filling Erlenmeyer flasks up to the neck with whole egg melange, immersing the flask in a constant temperature water bath, adding the yeast suspension and providing slow mechanical agitation to prevent settling of the yeast cells. The agitation was not severe enough to draw air into the body of the liquid. The progress of the fermentation was followed by means of removing 2.0-ml. aliquots of the liquid at intervals and determining the residual reducing sugar according to an adaptation of the Somogyi method *(16)*. Addition of the precipitating solutions used in this method [$Ba(OH)_2$ and $ZnSO_4$] stopped the fermentation.

The degree of yeastiness and other off-flavor imparted by the fermentation, and remaining in the dried product, was evaluated by a trained taste panel of seven judges on scrambled eggs prepared from the reconstituted materials. Samples were graded on the following basis: 10, no yeast flavor; 8, definite yeast flavor; 6, pronounced yeast flavor; 4, very pronounced yeast flavor; 2, intense yeast flavor; and 0, extreme yeast flavor.

Comparisons were made according to a randomized complete block design *(15)* if fewer than 5 samples were being evaluated and according to a balanced incomplete block design *(4)* for greater numbers. The results were analyzed by analysis of variance. Reference to significance pertains to the 5 percent level.

EXPERIMENTAL RESULTS AND DISCUSSION

Effect of pH and of Yeast Concentration. The influence of these factors on the time required to completely ferment the glucose was studied manometrically. The 2.0-ml. portions of whole egg melange in each Warburg vessel were fermented under a nitrogen atmosphere at 30° C. with varying amounts of *T. monosa* and at different pH values. The results of these tests are shown in Table 1. It is evident that the fermentation

TABLE 1

Effect of pH on Time Required for Glucose Removal from Whole Egg Melange [d]

Yeast added per vessel (dry basis)	Time to complete fermentation				
	Initial pH				
	7.4	6.9	6.4	5.9	5.4
mg.	*min.*	*min.*	*min.*	*min.*	*min.*
4	122	116	....	83	75
9	75	....	73	57	54
22	45	45	44	38	36
44	37	35	....	29	26

[d] Manometric method, 2.0 ml. whole-egg melange per vessel, *T. monosa* (0.10 ml.) in side arm, N_2 atmosphere, 30° C.

rate is not appreciably altered by lowering the initial pH until a pH of less than 6 is attained. However, it appears doubtful, from a practical standpoint, whether the increase in rate obtained below pH 6 would warrant the acidification.

Effect of Incubation Temperature. Manometric estimation of the time required by 10 mg. of *T. monosa* (dry weight) to ferment the glucose in 2.0 ml. egg at different temperatures served to provide information on this variable. A portable refrigeration coil was used in the Warburg water bath to maintain temperatures below that of the room. It is apparent from the results shown in Table 2 that the optimum temperature lies in the vicinity of 30° C. and increasing the temperature a few degrees above this value has little effect. All of the vat-type fermentations in filled Erlenmeyers to be described were incubated at 30° C.

Effect of Yeast Concentration on Rate of Fermentation and on Residual "Yeastiness" in the Lyophilized Product. The 500-ml. portions of whole egg melange, contained in 500-ml. Erlenmeyer flasks, were

[e] Since the date of submitting this manuscript for publication, two resting-cell processes for the fermentation of egg white have appeared in the literature. One process employs yeast *(8)* and the other a *Streptococcus (12)*.

TABLE 2

Effect of Temperature on Time Required for Glucose Removal from Egg Melange [a]

Temperature	Time to complete fermentation
° C.	min.
10	270
17	135
24	92
31	62
38	68

[a] Manometric method, 2.0 ml. whole-egg melange per vessel, 10 mg. *T. monosa* (dry basis) in 0.3 ml. in side arm, N_2 atmosphere, 30° C.

placed in a 30° C. constant temperature bath and varying amounts of the suspension of *T. monosa* added. The rate of fermentation was followed by means of the Somogyi reducing sugar method, aliquots of 2.0 ml. being taken every 15 minutes. Each fermentation flask was removed within 30 minutes after the fermentation was completed and the sample immediately shell-frozen in dry ice-acetone and lyophilized. Comparison of the "yeastiness" in the lyophilized fermented samples was judged according to a randomized complete block design. The results are shown in Table 3. It was desirable to select the fermentation conditions which

TABLE 3

Effect of Yeast Concentration on Fermentation Time and Residual "Yeastiness" in Lyophilized Product

T. monosa per 100 ml. whole egg	Time to complete fermentation	Yeast off-flavor [f]
g. (dry basis)	min.	
1.0	< 30	5.2
0.5	40	5.9
0.15	80	7.0
0.07	150	7.4
Control (not fermented)	....	9.3

[f] A score of 10 indicates no yeast flavor; 0 signifies extreme yeast flavor. There was a significant difference between the control and all experimental samples. Also, the 1.0 and 0.5 percent samples were significantly more "yeasty" than the 0.15 and 0.07 percent samples.

would minimize development of adventitious flora but at the same time also reduce the amount of yeast used to a minimum. Since reducing the yeast content below 0.15 g. (dry basis) per 100 ml. of egg melange apparently did not further diminish the detectability of the yeast flavor, this amount has been routinely used in a 2-hour fermentation at 30° C. for the preparation of glucose-free egg powder for storage experiments.

Comparison of Various Yeasts. Six different yeast cultures were compared as to their fermentation rates on whole egg melange and residual yeastiness or other off-flavor in the lyophilized fermented products. The cultures were prepared in identical manner on the medium previously described and the comparisons were made with the freshly prepared cell suspensions. The vat-style method was used for the fermentation, and the concentration of yeast was 0.15 g. (dry basis) per 100 ml. whole egg melange in each case. The progress of the fermentations is plotted in Figure 2 and is shown to proceed in a nearly linear manner. For the judging of residual yeastiness, the scrambled egg samples prepared from the reconstituted lyophilized products were compared according to a balanced incomplete block design (Table 4).

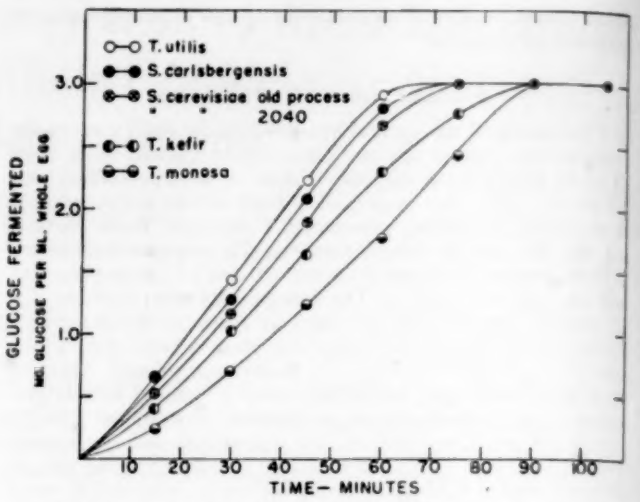

FIG. 2. Removal of glucose from whole egg melange by different yeasts at 30° C. (0.15 g. yeast (dry basis) added per 100 ml. egg in each case.)

TABLE 4

Comparison of Various Yeasts [g]

Yeast	Time to complete fermentation	Yeast off-flavor [h]
	min.	
S. carlsbergensis	70	8.8
S. cerevisiae 2040	75	8.8
S. cerevisiae old process	78	8.7
T. monosa	88	8.1
T. kefir	85	6.7
T. utilis	65	7.8
None (lyophilized control)	....	9.4

[g] Method: Vat-style, 0.15 g. yeast (dry basis) per 100 ml. whole egg melange, 30° C.

[h] Scores as in Table 3. There was a significant difference between the control and all experimental samples. The three *Saccharomyces* samples had significantly less off-flavor than the remaining three and the *T. monosa* and *T. utilis* had significantly less off-flavor than the *T. kefir*.

The results indicate that the relative fermentative abilities of the various yeasts tested are not widely different. From the standpoint of maximum fermentation rate combined with minimum residual off-flavor, *S. cerevisiae* appears to be an ideal choice.

A comparison was also made of the bakers' yeast *(S. cerevisiae)*, available commercially in 1-lb. cakes, with the laboratory-prepared cells of *S. cerevisiae* 2040. The fermentation rates were compared on an equal-solids basis (0.5 percent wet weight of commercial yeast = 0.15 percent dry basis). The commercial bakers' yeast appeared quite satisfactory as far as fermentation rate and palatability of product were concerned (Table 5).

TABLE 5

Comparison of Commercial Bakers' Yeast with Laboratory-Grown S. cerevisiae [i]

Yeast	Time to complete fermentation	Yeast off-flavor [j]
	min.	
Commercial bakers' yeast A (1 day old)	77	8.2
Commercial bakers' yeast B (6 days old)	83	8.3
Laboratory-grown *S. cerevisiae* 2040	70	8.7

[i] Method: Vat-style fermentation, 0.15 g. yeast (dry basis) per 100 ml. whole-egg melange, 30° C.

[j] Scores as in previous tables. The differences in off-flavor between the three fermented samples were not significant.

By-products of Yeast Fermentation. The products of the resting-cell yeast fermentation are chiefly ethyl alcohol and carbon dioxide which are, of course, volatilized during the drying step. Limited yeast plate-count measurements indicate that no significant increase in viable yeast count occurs during the 2- to 3-hour fermentation process under essentially anaerobic conditions. This is also suggested from the essentially linear nature of the fermentation curves (Figures 2 and 3). There were only negligible changes in pH, volatile acid, and lactic acid. This is in contrast to the usual commercial egg-white process (Table 6).

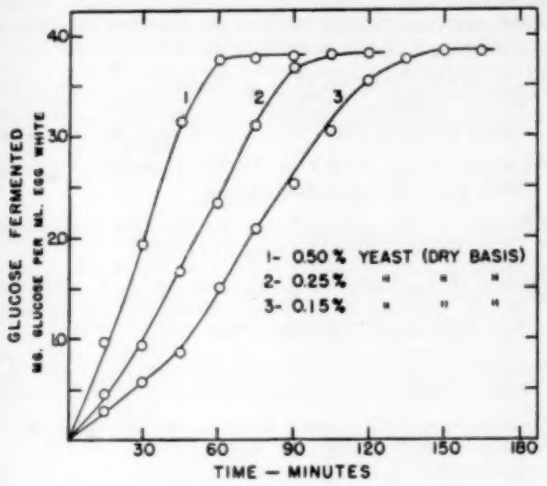

FIG. 3. Removal of glucose from liquid egg white by *T. monosa* at 30° C. (Percent yeast indicates yeast added (dry basis) per 100 ml. of egg white.)

Removal of Glucose From Liquid White and Yolk Before Drying. The resting-cell yeast fermentation may be just as readily applied to egg white and yolk. The rate of glucose removed from liquid white with different concentrations of *T. monosa* is illustrated in Figure 3. The initial pH of the white was 9.2; it dropped during the vat-type fermentation to 6.6 and was 7.0 to 7.6 at completion of the fermentation. These changes in pH may be attributed to carbon dioxide evolution and escape, since only negligible amounts of other acids are produced during the process (Table 6). The rate of glucose removal from liquid yolk was also studied by the vat-type fermentation. Relative times required by *T. monosa* to remove the glucose from whole egg melange, liquid white and liquid yolk are illustrated in Table 7.

TABLE 6

By-products from Yeast Fermentation as Compared to Those Present in Commercially Prepared Egg Albumen

Sample	pH (reconstituted)	Lactic Acid [k] (moisture-free basis)	Volatile Acids as Acetic (moisture-free basis)
		%	%
Lyophilized whole egg (not fermented)	8.9	0.04	0.01
T. monosa fermented whole egg (lyophilized)	8.9	0.05	0.03
S. cerevisiae 2040 fermented whole egg (lyophilized)	8.9	0.04	0.03
Lyophilized egg white (not fermented)	9.9	0.07	0.02
T. monosa fermented white (lyophilized)	9.8	0.07	0.05
Powdered commercial albumen A	6.0	1.10	0.39
Powdered commercial albumen B	7.5	1.25	1.20
Flake commercial albumen C	6.1	2.30	0.32
Flake commercial albumen D	5.4	0.69	1.05

[k] Many processors add lactic acid before drying to retard putrefaction; the values for the commercial albumens therefore do not necessarily represent lactic acid produced by the fermentation.

TABLE 7

Removal of Glucose from Liquid Whole Egg, White and Yolk by Resting-Cell Yeast Fermentation at 30° C.

Amount of *T. monosa* (dry basis) per 100 ml. liquid egg	Time to complete fermentation		
	Whole egg pH 7.4 3.20 mg. glucose per ml.	Egg white pH 9.2 3.85 mg. glucose per ml.	Egg yolk pH 6.0 1.85 mg. glucose per ml.
g.	*min.*	*min.*	*min.*
1.0	<30	....	....
0.5	40	60	....
0.25	....	100	....
0.15	80	135	60
0.07	150	....	90

Commercial Application. On the basis of information obtained from laboratory-scale studies, the process was applied in a commercial plant. Three pounds of fresh bakers' yeast were added in a slurry to 1200 lbs. of thawed whole egg melange which had been warmed to 30° C. This amount of yeast corresponded approximately to a level of 0.07 g. (dry basis) added per 100 ml. whole egg melange which at 30° C. would be expected to require 2½ hours to remove the glucose. Actually, about 3 hours were required, but this was understandable, since the temperature dropped during the process to about 24° C. The rate of fermentation was followed by means of a quick test based upon the Somogyi method. This test was as follows: 5 ml. of whole egg melange was mixed thoroughly for one minute in a 50-ml. glass-stoppered mixing cylinder with 25 ml. of water and 10 ml. each of the Somogyi precipitating reagents [$Ba(OH)_2$ and $ZnSO_4$]. The mixture was filtered through a folded filter paper and 5 ml. of the filtrate was heated with 5 ml. of the Somogyi copper reagent over a Bunsen burner to the boiling point and then gently boiled for 1½ minutes. The presence of glucose was indicated by the formation of a precipitate which varied from a copious reddish orange at the start of the fermentation to a light yellow green, and finally the absence of glucose was indicated by the solution remaining clear blue after boiling. The test was sufficiently sensitive to form a readily detectable precipitate when 97 percent of the glucose had been fermented.

The glucose-free melange was immediately spray-dried to 3.5 percent moisture. Another 1000 lbs. of the original, thawed whole egg melange was also spray-dried (without fermentation) under the same condition to 3.5 percent moisture and served as the control. Both samples were pasteurized at 142° F. (61° C.) for 4 minutes, before spray-drying, a procedure which reduced the yeast count in the fermented batch to zero. The dried samples were evaluated by the trained taste

panel both as to general off-flavor and residual yeastiness and the results are given below:

Sample	General off-flavor	Yeast off-flavor
Lyophilized unfermented egg	9.7	9.9
Spray-dried control	9.3	9.8
Spray-dried fermented	9.5	9.7

It was observed that the spray-dried fermented sample was at least as high in initial quality as the spray-dried control. Residual "yeastiness" was not detectable to a significant degree in the fermented spray-dried sample. It would appear from these results that the plant-scale operations of pasteurization and spray-drying removed the yeast flavor and odor much more effectively than did the laboratory lyophilization process.

CONCLUSIONS

The removal of glucose from whole egg melange by resting-cell yeast fermentation is shown to proceed in an essentially linear manner, as expected, following a slight initial lag period. The following factors affecting the fermentation process and the quality of the glucose-free product were considered:

1. The process proceeds rapidly at the normal pH of whole egg melange (7.4) but the rate is increased by decreasing the pH below 6. The fermentation rates were determined over the pH range of 7.4 to 5.4.

2. Fermentations were carried out over a range of temperatures from 10° C. to 38° C. Approximately 4 to 5 times as long a period was required to remove the glucose at 10° C. than at the optimum of 30° C.

3. The time required to remove the glucose varied with the yeast concentration but not in a linear fashion. The use of 0.07 to 0.15 percent (dry weight of yeast per 100 ml. of egg melange) of yeast at 30° C. was generally adopted as the condition favoring rapid fermentation (2 to 3 hours) with minimum residual yeastiness in the resulting lyophilized glucose-free powders.

4. Six different yeast strains, grown on identical media, were compared as to fermentative rate and as to the residual foreign flavor imparted to the resulting glucose-free powder. *Torulopsis utilis*, although slightly superior as to fermentative rate, imparted a distinct foreign flavor. The two strains of *S. cerevisiae* used and *S. carlsbergensis* appeared to be equal choices combining rapid fermentative rate with minimum foreign flavor.

Commercially available *S. cerevisiae* (bakers' yeast) was found to be nearly as satisfactory as the laboratory-grown strains.

5. The laboratory process was applied on a commercial scale and proceeded according to predictions. Three lbs. of fresh bakers' yeast was used to ferment 1200 lbs. of whole egg melange in about three hours at 25-30° C. The fermented liquid was pasteurized at 142° F. (61° C.) for 3 to 4 minutes and spray-dried to 3.5 percent moisture. The initial organoleptic quality of the powder was at least as high as a standard powder prepared from the same batch of liquid. The commercial processing reduced the yeastiness to the point where it was not significantly detectable to a trained taste panel.

6. The application of the resting-cell yeast process to egg white and yolk is illustrated.

ACKNOWLEDGMENT

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The Application of Peracetic Acid Germicidal Washes to Mold Control of Tomatoes[a]

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A new bactericide-fungicide, peracetic acid, is described. Studies of mold control in which dilute peracetic acid solutions have been applied to tomatoes in baskets are discussed. Peracetic acid solutions have been found effective in combatting mold growth on tomatoes over 2-3 day holding periods. Strikingly increased juice yields have been obtained from peracetic acid treated tomatoes as compared with untreated tomatoes in controlled large scale field tests. The method has been also extended to the prevention of mold growth on grapes.

INTRODUCTION

With the institution of microbioloical control, increasing attention has been focused on the nature and extent of organism incidence on raw materials entering the processing plant. Microorganism contamination of fruits and vegetables has long been recognized as a major contributing influence to loss of flavor, deterioration and spoilage.

Tomatoes, in particular, present a crop especially susceptible to mold spoilage. In hot, humid weather, prevalent during the tomato season in many areas of the United States, mold growth on the fruit, bruised and broken during handling, causes considerable difficulty. This is accentuated during peak periods of production or in shipment from areas distant from the processing plants, when periods of 1-3 days may elapse from picking to processing.

It is standard practice in tomato processing plants to maintain constant control of the product by mold counts and sorting and trimming on the inspection line. Mold growth on tomatoes is thus important as it affects product quality, causes production difficulties, and economic losses through spoilage and decreasing yields.

It was found in our laboratories that peracetic acid had high bactericidal and fungicidal activity with various promising features, indicating utility as a germicidal wash for fruits and vegetables. This has recently been developed into a process finding commercial application for mold control of tomatoes and related products. It is the purpose of this paper to describe controlled pilot scale and commercial scale treatment of tomatoes made over the course of the last few years.

Peracetic acid is an aliphatic peracid of structure CH_3COOOH. This material is sold as a stable 40 percent peracetic acid solution and information relating to detailed analysis, stability, solubility and chemical reactivity is available *(2)*. The commercial 40 percent product is colorless, of typically pungent odor, with handling characteristics somewhat akin to glacial acetic acid. It can be readily diluted with water for the formulation of germicidal and sanitizing washes *(3)*. A 1 percent aqueous solution, so obtained, has a pH of approximately 2.5. Pure peracetic acid is a weak acid, weaker than acetic, with an ionization constant, K, approximating 10^{-8}. Where desired, adjustment in pH of dilute solutions can be made with alkali. Dilute solutions are handled without special precautions and are compatible with surface active materials of the anionic, non-ionic, and cationic type.

Structurally, peracetic acid combines the active oxygen characteristics of a peroxide within the molecule of acetic acid, with properties at once different, qualitatively and quantitatively, from the properties of hydrogen peroxide and acetic acid from which it is derived *(5)*. The specificity of peracetic acid as an oxidant in organic synthesis has been detailed in numerous papers *(4, 9)*. While catalase almost instantly decomposes hydrogen peroxide, it is without action on peracetic acid in solution. Actually, dilute peracetic acid solutions rapidly inactivate enzymes of the oxidase and peroxidase types.

Peracetic acid exhibits greatly superior bactericidal activity over both hydrogen peroxide and acetic acid. Table 1 indicates the bactericidal action of peracetic acid against various organisms. These results were obtained using a modified phenol coefficient method *(8)*, with peracetic acid being added to the organism suspension. Concentrations are given in percent peracetic acid (100 percent) present in phosphate buffer and nutrient broth. In order to eliminate the acidity effect from consideration, the dilute peracetic acid solutions were adjusted to pH 7 with sodium hydroxide.

TABLE 1

Bactericidal Action of Peracetic Acid

Organism	*Peracetic Acid Concentration Required* [b]	
	In Phosphate Buffer	In Nutrient Broth
	Percent	*Percent*
Escherichia Coli	0.001	0.020
Micrococcus Pyogenes Var. Aureus	0.001	0.020
Pseudomonas Aeruginosa	0.005	0.025
Bacillis Subtilis	0.300	0.500
Aspergillus Niger	0.005	0.050
Penicillium Roqueforti	0.005	0.050

[b] Killing in 10 but not in 5 minutes.

Peracetic acid has similarly been reported to be very effective against spore-forming organisms. e.g. *B. thermoacidurans* and the flat sour organisms *(7)*.

Of major interest in the application of any bactericidal agent to a food surface is the question of residues. Peracetic acid should be considered as a temporary bactericide, since it breaks down gradually on appli-

[a] Presented at the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 24, 1950.

cation to a surface through the following series of reactions:

(1) $CH_3COOOH + H_2O \rightleftarrows H_2O_2 + CH_3COOH$
(2) $CH_3COOOH \rightarrow \frac{1}{2} O_2 + CH_3COOH$
(3) $H_2O_2 \rightarrow H_2O + \frac{1}{2} O_2$

The rate of decomposition is dependent upon the nature of the surface, the water used for dilution, pH, temperataure, etc. Any residual bactericidal action obtained is limited to that of acetic acid itself. The ultimate products of decomposition are acetic acid and water, non-toxic and free-rinsing products. These are readily removed, together with any freely soluble peracetic acid possibly remaining, in the water wash step preceding processing of the produce. Toxicity tests on peracetic acid have also been carried out *(3)*.

EXPERIMENTAL

Tomato Washing. One-half bushel baskets of tomatoes, selected at random from one source, were divided into lots of a dozen baskets each. Three dozen baskets were then sprayed with a 0.3 percent peracetic acid solution (0.75 percent of the 40 percent product), containing 0.1 percent of Nacconal NR. The baskets were set aside for holding along with three dozen baskets containing untreated tomatoes. At daily intervals, a dozen baskets from each category, treated and untreated, were separately processed to juice in pilot plant equipment. Mold counts using the standard Howard cell technique *(1)* were made on the resultant products. This was done for 1 day, 2 days, and 3 days holding periods. In addition, a dozen baskets, untreated, were juiced at the start of the holding tests (zero time) to give a reference point for mold count evaluation. To avoid any possibility of subjectivity, the commercial practice of cutting away bad areas of the tomato was not resorted to. The entire contents of each basket were included in the runs made.

The juicing procedure employed involved in sequence: a water wash, a break in a Fitzpatrick chopper, pumping through a Citroflash pasteurizer (30 sec. at final temperature of 160°-180° F. (70°-80° C.) and removal of pulp and seeds in a finishing machine. A blended juice sample representing each dozen baskets of tomatoes was obtained for mold counts. It can be seen from the results in Table 2, that the peracetic acid treatment held the mold count of the tomatoes virtually static for two days with some increase noted for the third day. By contrast, the rapidly accelerating mold growth in the untreated samples should be noted. Organoleptic evaluation of the canned processed juice showed flavor deterioration in the sample prepared from the untreated tomatoes held for three days. The treated samples showed no such deterioration. The peracetic acid treatment has been found to have no effect on the flavor of the processed tomato products.

TABLE 2

Effect of Tomato Washing with Peracetic Acid on Mold Count in the Juice

Holding Time	Mold Count	
	Treated [c]	Untreated
Hours		
0	23	23
24	24	49
48	25	60
72	48	85

[c] 0.3 percent peracetic acid used.

Table 3 shows the results obtained in commercial scale experimental runs wherein 17 tons of tomatoes were treated and 17 tons were left untreated in parallel tests. Particular attention was paid in these experiments to the relationship between mold growth and juice yields. Spray solutions were formulated containing 0.3 percent peracetic acid and 0.05 percent Nacconal and were applied to tomato baskets, tiered three high, with a power sprayer under field conditions. Using a boom, it was possible to spray the tiered baskets layer by layer. With the equipment used, a 4-second per basket spray schedule was found sufficient to give adequate coverage of the tomatoes in the basket.

TABLE 3

Effects of Tomato Washing with Peracetic Acid on Yields and Mold Counts

	Peracid-Treated	Control
Weight of Tomatoes Used	34,150 lbs.	34,190 lbs.
Weight of Juice Obtained	21,850 lbs.	20,000 lbs.
Percent Yield	64	58.5
Percent Increase in Yield	9.3	....
Mold Count (Average)	15	17
Mold Count Pilot Plant Samples [d]	22	48

[d] No trimming.

The treated and untreated baskets were allowed to stand for one and a half days. Weather conditions over this period were hot and humid. Visual examination at this point indicated an abundance of mold filaments on untreated baskets, considerable softening of the fruit with liquid exudation, and a characteristic odor. Treated tomatoes appeared to have suffered little or no change during the same period. It was interesting to note the tremendously greater fly popoulation on untreated baskets of tomatoes.

The tomatoes were then sent through a standard production juice line. Cutting was kept to a minimum, commensurate with keeping counts well within specification limits.

As a further test of the efficiency of the treatment, a dozen baskets of treated and untreated tomatoes, removed from the larger lots, were separately processed in pilot scale equipment without sorting or trimming. Data for these runs are included in Table 3 for comparison.

The efficacy of peracetic acid treatment in reducing mold growth and thereby increasing tomato product yield is demonstrated by the results in Table 3.

GRAPES

Ten boxes of Concord grapes from a single source were divided into lots of 2, 4, and 4. Four boxes were treated with a 0.3 percent peracetic acid solution containing 0.1 per cent Nacconal and set aside for holding. Four boxes of untreated grapes were likewise set aside as controls. Two boxes of grapes were immediately juiced and canned. The four boxes of treated and untreated grapes were held for 3 days at 75° F. (24° C.) and then separately juiced.

The procedure used in laboratory processing of the grapes was as follows:

The grapes were initially hand-stemmed in clean wash water and transferred to a hydropulper with the addition of 10 percent water. The thick slurry resulting was strained through a colander to remove seeds, skin, and large particles. The juice was then canned, without clarification, so that mold count studies could be made.

Mold counts were run on the processed grape juice by the standard technique. Results are indicated in Table 4, wherein the ability of peracetic acid to maintain static mold counts is again demonstrated. The control untreated grapes showed a rapidly mounting mold count compared to absence of mold growth on the treated grapes.

TABLE 4

Effect of Grape Washing with Peracetic Acid on Mold Count in the Grape Juice

Holding Time	Mold Count in Unfiltered Juice	
	Treated	Untreated
Hours		
0	4	4
72	4	20

SUMMARY

A new bactericide-fungicide, peracetic acid, is described. Tomatoes have been treated with dilute peracetic acid solutions in attempts to combat mold growth. Ability to maintain virtually static mold counts on tomatoes over a two to three day holding period is indicated by the results. The deleterious effect of mold growth on tomato product yield is illustrated. In parallel large scale runs with peracetic acid, significant increases in juice yields were obtained from treated as against untreated tomatoes. Experimental sprayings have been extended to grapes with equally satisfactory results. Treatments can be made through spraying or dipping.

The use of peracetic acid germicidal washes for tomatoes shows promise for (a) production of low mold count quality products (b) increasing production yields (c) lowering cutting costs and (d) increasing plant operational flexibility, and extending the season by permitting transportation of products from more distant growing areas to the processing plant. Treatment costs are low.

ACKNOWLEDGMENT

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Post-Mortem Changes in Stored Meats. II. The Effect of Atmospheres Containing Carbon Dioxide in Prolonging the Storage Life of Cut-up Chicken[a,b]

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The effect of atmospheres containing carbon dioxide in prolonging the storage life of cut-up chicken is discussed. The ratio of keeping time of a sample in the presence of carbon dioxide to its keeping time in air is a linear function of carbon dioxide concentration.

Deterioration of cut-up chicken held at refrigerator temperatures above freezing is due primarily to the proliferation of slime-forming bacteria on the exposed surfaces. In the first paper of this series, Ayres, Ogilvy and Stewart *(1)* observed that the bacteria responsible for slime and off odor of stored cut-up poultry from several sources were closely related types of the genera *Pseudomonas* and *Alcaligenes*. The type of spoilage and the types of organisms noted appeared to be very similar to those reported for beef and other fresh meats by many investigators, notably Haines *(8)*. It was shown that the microbial flora concerned was capable of multiplication even at 32° F.(0° C.).

A holding method which would give added shelf life without detracting in any way from quality of this product would be of considerable importance. The use of storage atmospheres containing carbon dioxide offers interesting possibilities in this regard.

Many studies have been reported on the effect of carbon dioxide on the growth of microorganisms. In 1889, Frankel *(7)* showed that microorganisms varied widely in their susceptibility to carbon dioxide, proliferation of some being completely suppressed while others were less affected. His findings have been substantiated by work of later investigators.

Fortunately, carbon dioxide is able to retard reproduction of those organisms which ordinarily cause surface deterioration of meat. This has been demonstrated by Kolbe *(10)*, Haines *(9)*, Empey and Vickery *(6)*, Tomkins *(16)*, Moran, Smith and Tomkins *(11)*, and

[a] Presented before the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 22, 1950.

[b] Appreciation is expressed to the Pure Carbonic Company, a division of Air Reduction Co., Inc., N. Y., N. Y. for support, in part, of this research.

[c] Present address, Armour and Company, Chicago, Ill.

[d] Journal Paper No. J-1800 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 1161.

Scott *(13)* in the case of beef; by Callow *(3)* for pork; and by Coyne *(4, 5)* for fish. Attempts by Smith *(14, 15)* to prolong keeping time of poultry by high concentrations of carbon dioxide were not successful. The exposed flesh of eviscerated birds developed an unpleasant brown color; New York dressed birds evidenced swelling at the vent and also green discolorations due to autodigestion of the abdominal wall.

A disadvantage of carbon dioxide is its production of discolorations or loss of "bloom" in fresh meat when used in high concentration. Brooks *(2)* observed that levels of carbon dioxide above approximately 20 percent produced this defect in the case of beef. The discoloration was ascribed to the acceleration by carbon dioxide of the oxidation of hemoglobin to methemoglobin.

The present investigation was undertaken in order to determine the value of carbon dioxide for storage of cut-up chicken and the conditions under which it could be best employed.

EXPERIMENTAL

Cut-up fryers (2½ to 4 lb.) were obtained from 3 sources; (1) live birds from the Iowa State College Poultry Farm were killed by bleeding; struggle was eliminated by application of an electric shock. Birds were then immersed for 30 seconds in water at 130° F. (54.5° C.), rough picked by machine, and finished by hand. Following evisceration and washing, fryers were cut up and air chilled at 32° F. (0° C.) for 4 hours or overnight depending on the time of day; (2) frozen cut-up packaged chickens were purchased from a commercial concern and stored at —10° F. (—23.3° C.). These were thawed 24 hours at 40° F. (4.4° C.) immediately before use; (3) fresh cut-up fryers were obtained from a local produce house immediately after slaughter and cold water chilling and were used in experimental runs on the same day.

All birds were cut up in the same way to give, in addition to giblets, 2 legs, 2 thighs, 2 wings, ribs, back, and 2 pieces of breast.

One-quart and two-quart Mason type jars with one-hole rubber stoppers were found most suitable for use as storage containers. Fittings of glass and rubber tubing provided a means of changing atmospheres, screw clamps on the rubber tubing were employed for isolating the enclosed atmospheres.

The basic control apparatus consisted of a Fisher Unitized Precision gas analyzer (Orsat type), with a built-on glass manifold and mercury manometer (Figure 1). After a sample jar had been attached to the manifold, communication was established either to the gas analyzer at *B* or to the manifold by means of the 3-way stopcock, *A*. A Cenco-Hyvac vacuum pump connected to the manifold at *C* allowed evacuation of sample jars. Carbon dioxide and oxygen from cylinders and air from the room were admitted to the manifold through stopcocks *D*, *E*, and *F*. The mercury manometer, G, was employed to control the amounts of individual gases added to evacuated jars and was also used to measure vacuums in jars after storage.

Pieces of chicken were placed in sterilized jars and 5 ml. of sterile distilled water were added to each jar to insure a relative humidity approaching 100 percent. In some cases the desired atmosphere was obtained by an evacuation method making use of the apparatus described in Figure 1. In other cases, the air in the sample jars was displaced by a stream of a CO_2-air mixture whose composition was controlled by calibrated glass flow meters. In a few experiments, a constant flow of humidified gas was maintained through sample jars stored in a refrigerator. (See Figure 2).

When flow meters were employed, the carbon dioxide concentration of the gas leaving the jars was measured by means of a Cambridge carbon dioxide analyzer (Model M), operating on the thermal conductivity principle.

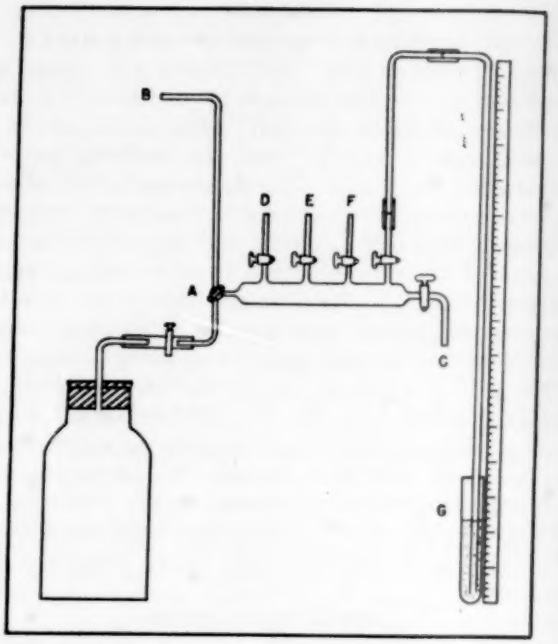

FIG. 1. Apparatus for changing atmospheres in storage containers.

Two general methods of storage were employed. In the first, chicken samples were sealed in jars containing the desired carbon dioxide level; no attempt was made to control changes in gas composition taking place during storage. In the second method, carbon dioxide percentages were maintained at a given level by application of a constant flow of gas or by use of the evacuation or displacement procedures at the necessary intervals.

Storage was carried out at 32°, 40°, 45°, and 50° F. (0°, 4.4°, 7.2°, and 10° C.) Samples were examined at intervals for changes in appearance and odor. Bacterial surface counts were made by the swab method described in the previous paper. Colonies from the resulting plates were picked and subcultured for subsequent classification according to morphological, cultural and physiological characteristics.

Keeping times of samples generally were based on the first observance of off-odor. In some cases, keeping times also were determined from the time required for bacterial counts to reach a level of 2×10^7 per square centimeter. A third method depended on the time required for a specified increase in carbon dioxide concentration to be noted in storage containers. Excellent agreement was obtained among the three methods.

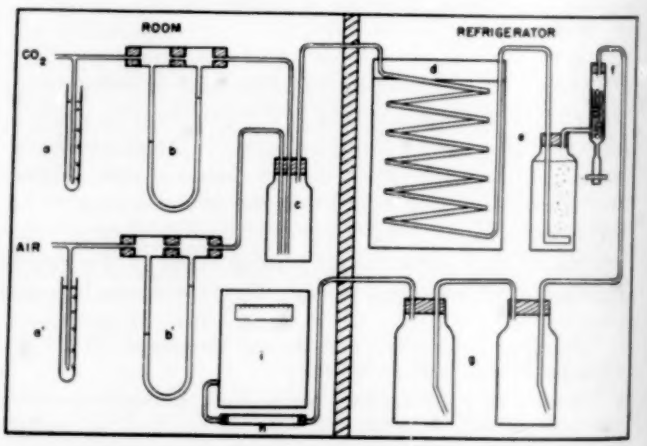

FIG. 2. Apparatus for constant flow of controlled carbon dioxide-air mixture. a, a′: pressure regulators; b, b′: flow meters; c: mixing chamber; d: submerged cooling coil; e: humidifier; f: trap; g: sample bottles; h: drying tube; and i: CO_2 analyzer.

RESULTS AND DISCUSSION

The effect of carbon dioxide level and temperature on the keeping times obtained for cut-up chicken from several sources is shown in Figures 3 and 4. For any given lot of chicken, storage life tended to be prolonged

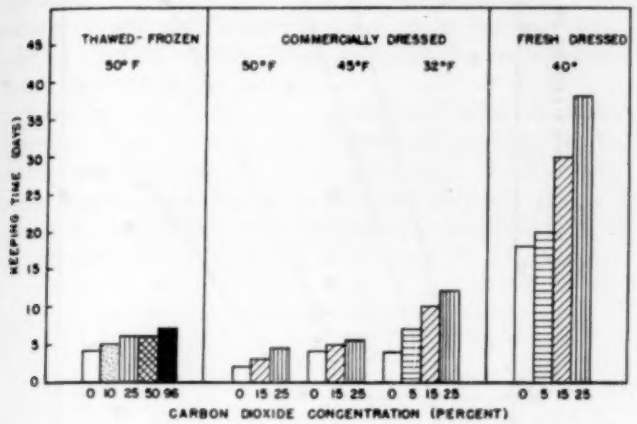

FIG. 3. Effect of carbon dioxide concentration, temperature and source of supply on the storage life of cut-up chicken.

as the carbon dioxide concentration was increased. Reduction of the storage temperature also resulted in an increase in storage life, both in the presence and absence of carbon dioxide. An interesting feature was the differences in keeping times obtained with the several types of chicken under the same conditions. These were observed not only with chicken from different sources but also with different pieces from the same batch and even from the same bird. In addition, the increases in keeping times resulting from increasing carbon dioxide levels for any given set of data were by

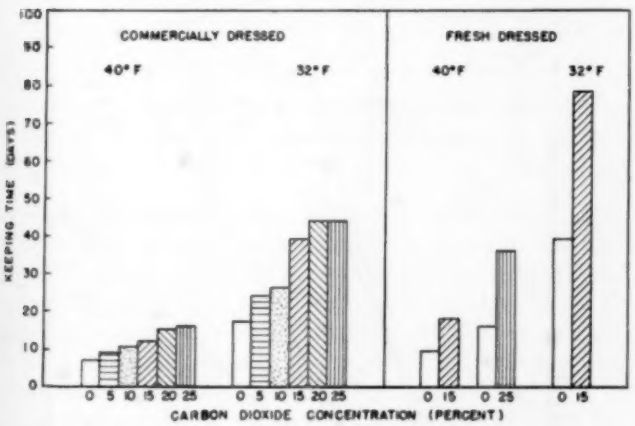

FIG. 4. Effect of carbon dioxide concentration, temperature and source of supply on the storage life of cut-up chicken.

no means regular. Obviously, measurement of keeping time alone did not constitute a satisfactory criterion for determining the effectiveness of carbon dioxide.

In order to better evaluate the influence of carbon dioxide on storage life, the ratio of keeping time in carbon dioxide to that in air was computed in all cases. The resulting quotient was termed the "storage index."

In Figure 5, storage indices for each type of chicken are plotted against carbon dioxide concentration. Storage index was increased by an increase in carbon dioxide level and a decrease in temperature. In addition, the source of the chicken had a pronounced influence on the slope of the curves. There were indications that storage index was a linear function of carbon dioxide level within the range 0 to 25 percent. To test this assumption, average values for storage indices were obtained from a run in which 4 pieces from the same batch of chicken were stored at 40° F. (4.4° C.) under each of six different carbon dioxide concentrations. In order to get a more accurate estimation of end points,

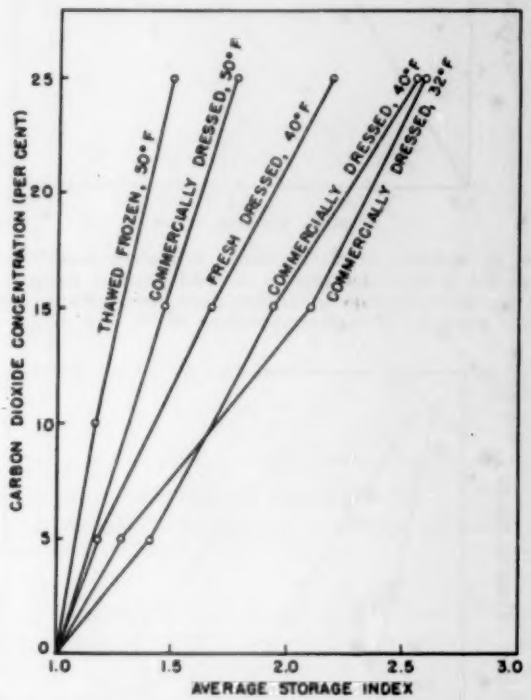

FIG. 5. Relation of storage index to carbon dioxide concentration for different types of cut-up chicken.

limits of storage were determined from bacterial growth curves rather than from off-odor production. The results appear in Figure 6. Apparently the relationship may be represented reasonably well by a straight line.

It was noted above, that storage life depended to a large extent on the source of chicken; storage index also was influenced by this factor. For instance, storage indices for chicken backs stored under the same conditions (15% CO_2, 40° F.) varied from 1.42 to 2.25. The lower value was obtained for chicken of good keeping quality while the higher figure applied to birds of poor quality. To a large measure it seemed likely that differences in initial contamination would account for these findings. In Figure 7, keeping times for various pieces of chicken are plotted against logarithms of initial bacterial counts. Again the relationship was found to be linear. A reduction in contamination gave a marked increase in storage life. The benefits derived from a reduced bacterial load were much greater at a

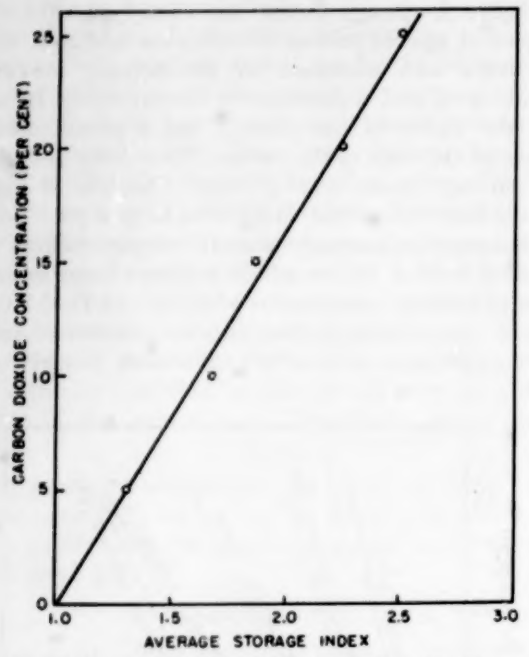

FIG. 6. Relation of storage index to carbon dioxide concentration for fresh, commercially dressed chicken thighs. Each point represents average of quadruplicate determinations on one batch of chicken. Storage temperature, 40° F. (4.4° C.).

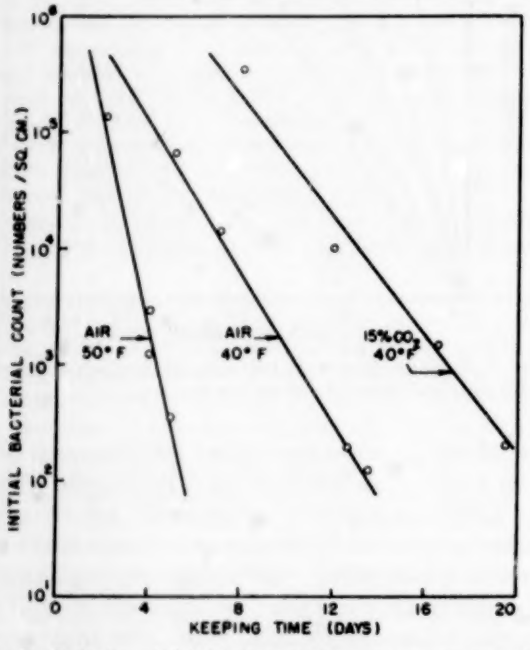

FIG. 7. Relation of initial bacterial count to storage life of cut-up chicken.

lower temperature as is shown by the difference in slopes of the curves for 50° F. (10° C.) and for 40° F. (4.4° C.). With any initial count, the addition of 15 percent carbon dioxide to the storage atmosphere resulted in a longer storage life although the relative effectiveness was greater with higher counts.

The shortcomings of keeping time and storage index as expressions of the influence of carbon dioxide and temperature on bacterial growth led to a study of growth curves of slime-forming bacteria. A series of

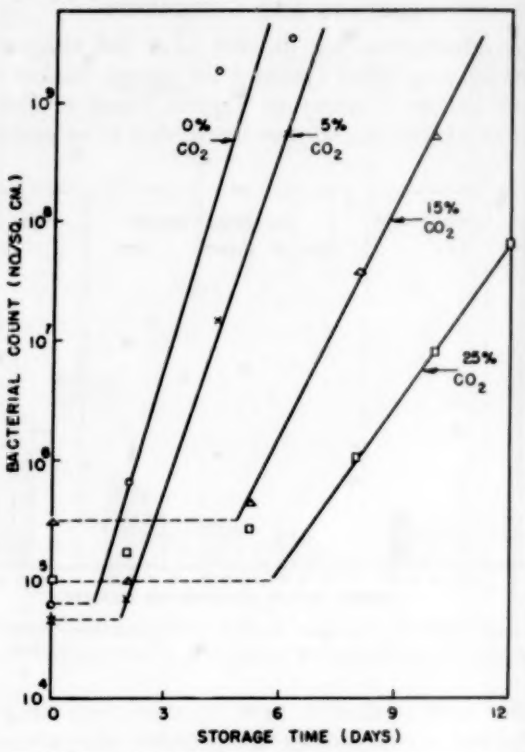

FIG. 8. Effect of carbon dioxide on growth curves at 40° F. (4.4° C.) of bacteria on chicken thighs.

counts from each sample was used in plotting a curve on semi-logarithmic paper. Figure 8 shows growth curves obtained from counts made on chicken thighs stored at 40° F. (4.4° C.) with atmospheres containing 0, 5, 15 and 25 percent carbon dioxide. The horizontal

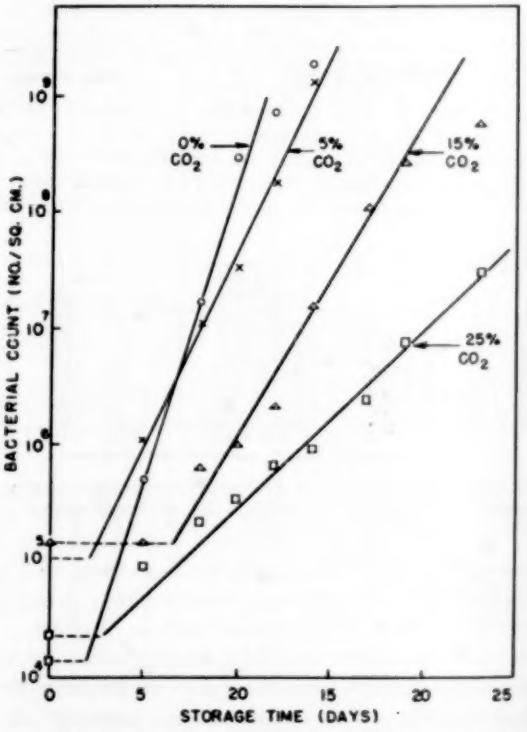

FIG. 9. Effect of carbon dioxide on growth curves at 32° F. of bacteria on chicken thighs.

distance from the initial count to the point of intersection with the logarithmic portion of the curve was considered to represent the lag time. Similar curves were prepared for 50° F. (10° C.) and 32° F. (0° C.); the latter are presented in Figure 9. At any of the temperatures studied, an increase in carbon dioxide level definitely decreased the slope of the linear part of the curve. There was a tendency for lag to increase with carbon dioxide concentration, although the results were not consistent in this respect.

Growth rates in terms of generation time were determined from the slopes of logarithmic portions of the curves. Logarithms of average generation times at each temperature were found to be approximately proportional to carbon dioxide concentration in the range 0 to 25 percent as is shown in Figure 10 (Run 4A).

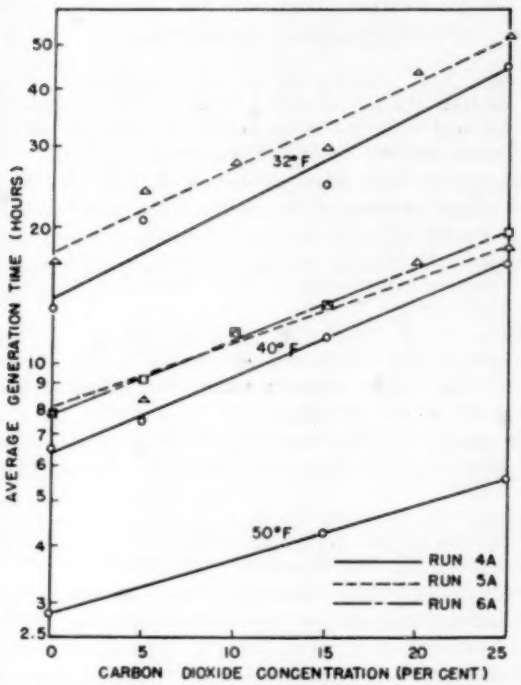

FIG. 10. Relation of carbon dioxide concentration to average generation time at various temperatures.

Average generation times obtained from other runs (5A and 6A) gave curves which were approximately parallel and in the same general area as corresponding curves from the first run. Apparently the logarithm of generation time is a linear function of carbon dioxide level, and similar results can be obtained with chicken from various batches.

An indication of the influence of temperature on growth rate may be obtained by comparison of the growth curves for identical carbon dioxide concentrations in Figures 8 and 9. A reduction in temperature increased the lag time and slowed the rate of bacterial multiplication in the logarithmic phase. This was found to be true with both carbon dioxide and air storage. For one experiment, logarithms of average generation times were plotted against temperature for carbon dioxide concentrations of 0, 15 and 25 percent (Figure 11). Straight lines were obtained indicating that the Arrhenius-van't Hoff equation applied to relation of growth to temperature in the range 32° to 50° F. (0° to 10° C.). A similar conclusion was reached by Scott *(12)* from a study of bacterial growth on beef muscle.

Particular attention should be called to the differences in slope of the curves in Figures 10 and 11. Considering Figure 11, it can be seen that the curves di-

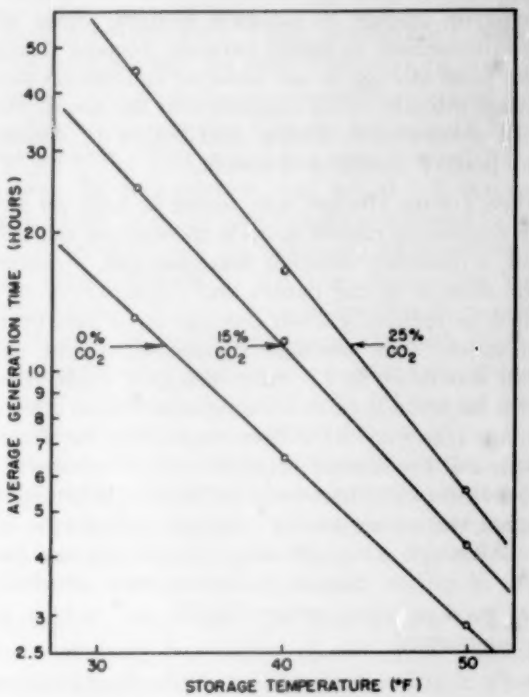

FIG. 11. Relation of temperature to average generation time at various carbon dioxide concentrations.

verge as temperature is reduced and become greater in slope as carbon dioxide concentration is increased illustrating the greater effectiveness of carbon dioxide at lower temperatures. The combined effects of temperature and carbon dioxide are greater than would be indicated by the sum of the individual effects of these factors. At 50° F. (10° C.) an increase in carbon dioxide concentration from 0 to 25 percent results in a two-fold increase in average generation time; at 40° F. (4.4° C.), the corresponding increase is approximately 2½ fold; at 32° F. (0° C.) it is about 3½ fold. The use of 15 percent carbon dioxide at 40° F. has the same effect on average generation time as a reduction in temperature to 34° F., and 25 percent carbon dioxide gives a greater retardation than any temperature short of one which would freeze the meat. Application of carbon dioxide at 50° F. (10° C.) is of much less practical value.

Expression of the influence of carbon dioxide or temperature in terms of generation time of the microbial flora concerned has the obvious disadvantage that the effect on lag time is not considered. Since a reduction of temperature and an increase in carbon dioxide level tend to extend the lag period, interpretations from Figures 10 or 11 give underestimates of the effectiveness of these agents.

Use of carbon dioxide concentrations above 25 percent was not considered practical because of the rapid discoloration which developed during storage when such levels were used. Some loss of bloom occasionally was observed with concentrations of 15 to 25 percent. This occurred with good quality chicken having unusually long shelf life.

Application of carbon dioxide storage for a few days followed by storage in air gave keeping times which were intermediate in length between keeping times resulting from storage in air alone or continuous storage in carbon dioxide. This suggests that the use of carbon dioxide atmospheres during distribution or display of cut-up poultry would be of benefit.

When cut-up chicken was sealed-in with an atmosphere containing carbon dioxide throughout the storage period, a different situation was observed. Solution of carbon dioxide in the tissues and utilization of oxygen resulted in reduced carbon dioxide levels and eventual anaerobiosis. The pressure diminished as the carbon dioxide was taken up. A microbiological study revealed that the bacterial flora developing under these conditions did not correspond to the flora responsible for slime formation, and the former organisms were influenced less by carbon dioxide than were the latter. When spoilage occurred, the accompanying odor was putrefactive in nature. Although some advantage in shelf life was gained by use of carbon dioxide in this manner, results were not as good as when carbon dioxide and oxygen levels were maintained.

Study of 163 cultures of bacteria isolated from cut-up chicken which had reached or were approaching the slimy condition indicated that the types causing sliminess were identical or similar to those reported in the previous paper. The great majority of cultures were considered to be members of the genus *Pseudomonas;* others were very similar to the description given for *Alcaligenes viscosus* in the sixth edition of Bergey's Manual. The latter organisms, while comparatively inert biochemically, show pronounced ability to hydrolyze fat. Temperature variations (32° to 50° F.) and changes in carbon dioxide concentration (0 to 25 percent) had no appreciable effect on the types of slime forming bacteria found. However, differences in predominant types were found among different lots of chicken. When chicken was stored in sealed jars with high carbon dioxide levels, growth of the slime-forming types was suppressed. Two general types were present in about equal numbers; the first group had characteristics of lactobacilli; organisms of the second group were gram-negative, facultative rod-shaped bacteria.

The similarity of bacterial types reported in the literature to cause sliminess of various kinds of meats leads us to the belief that carbon dioxide can be advantageously applied in storing any type of fresh meat.

SUMMARY

Atmospheres containing carbon dioxide have been shown to improve storage life of cut-up poultry at refrigeration temperatures above freezing. The effectiveness of carbon dioxide as measured by storage life of the chicken or by inhibition of slime-forming organisms was improved as the carbon dioxide concentration was increased or as temperature was reduced. Storage index (ratio of keeping time of sample in carbon dioxide to its keeping time in air) was a linear function of carbon dioxide concentration. Average generation time for the slime-forming bacteria appeared to be a logarithmic function both of the carbon dioxide concentration (0 to 25 percent) and of temperature (32° to 50° F.). A concentration of 25 percent carbon dioxide generally was considered to be the maximum proportion that could be employed because of the development of discolorations when higher levels were used. Keeping times of samples were markedly improved when initial bacterial loads were low.

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A Method for Maintaining Free Sulfur Dioxide Content in Wine[a, b]

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Based on the fact that polyethylene film is gas-permeable and reasonably moisture-proof, experiments have shown that it is possible to maintain the free sulfur dioxide content in wine by introducing into the wine one or several polyethylene bags with the required exposed surface area and containing the proper amount of bisulfite.

Sulfur dioxide is the sole legal preservative for wine, and it has been extensively used, particularly during the warm seasons, to stabilize wine and to prevent secondary fermentation in light sweet wines *(15)*.

Sulfur dioxide exists in wine in two forms, free and combined. Free sulfur dioxide is defined as "sulfur dioxide titratable with iodine," and it has been proved by several investigators that the preservative action of the added sulfur dioxide depends on its existence in the free state. The combined sulfur dioxide has little germicidal effect.

A review of the literature discloses that the problem of loss of free sulfur dioxide in wines and fruit juices has been known for a long time. The added sulfur dioxide combines with the aldehyde group of glucose and other substances in solution to form organic bisulfite compounds. This results in a complete loss of its original preserving power.

Ingram *(7)* illustrated the proportions of added sulfur dioxide remaining free in nutrient solutions. Solutions of dextrose, 4 percent and 40 percent were used and sulfur dioxide in varying concentrations was added. Results showed that in the 4 percent dextrose solution about three-fourths of the sulfur dioxide remained free. In the 40 percent dextrose solution only about one-fourth of the added sulfur dioxide remained free. This proves that sulfur dioxide does combine with the dextrose in solutions. This experiment also showed, unexpectedly, that the ratio of free to total sulfur dioxide increased markedly with the total quantity of sulfur dioxide added.

Müller-Thurgau and Osterwalder *(11)* stated that sulfur dioxide added to a fermenting juice is believed to combine with acetaldehyde, acetone, and other substances and will not prevent further fermentation. Kerp *(10)* specified that the increasing ability of glucose, acetone, and acetaldehyde to combine with sulfur dioxide compares with the increasing acidity of these substances to abolish its preservative power. Ingram *(8)* concluded that in relation to the preservative action of sulfur dioxide, the amounts added that go into combination are irrelevant. The preservative action is exerted only through the portions remaining free.

Downer *(5)* took unpreserved, concentrated orange juice, diluted it to natural strength and added 834 p.p.m. sulfur dioxide. This juice was then divided into two portions. To one portion was added 1.2 percent by volume of acetone, the other portion received no treatment. After 24 hours the untreated juice retained 646 p.p.m. sulfur dioxide in the free state. The treated juice had only 128 p.p.m. free sulfur dioxide remaining. Both portions of juice were inoculated with live yeast. The untreated juice had no living yeast cells at the end of 5 days. The portion treated with 1.2 percent acetone gave increasingly larger concentrations of yeast cells and on the 5th day active fermentation commenced. This experiment showed conclusively that acetone will tie up free sulfur dioxide. It also shows that free, and not added or total sulfur dioxide, is the determining factor in the prevention of yeast growth.

Ingram *(7)* also found that fermentation occurred in juices containing free sulfur dioxide that was not in large enough quantities to stop fermentation. The fermentation continued at a rate that was correlated with the concentration of the free sulfur dioxide. The more free sulfur dioxide, the slower became the rate of growth. There was no correlation between combined sulfur dioxide and growth stoppage. These results clearly indicate that free, and no combined, sulfur dioxide exerts a preservative effect in juices.

Feigenbaum and Israelashvili *(6)* studied the effect of various factors on the chemical reaction between glucose and sulfur dioxide and found that the amount of sulfur dioxide bound to glucose depends on the acidity of the medium and the quantity of glucose present. Additions of 1.5 g. of citric acid to a system containing 20 g. of concentrated citrus juice and 0.5 g. of glucose, produces binding of 96 percent of the sulfur dioxide.

Woodroof and Cecil *(14)* stated that sulfur dioxide was lost during fermentation of fruit juice because it is carried away by the carbon dioxide liberated. Bioletti and Cruess *(2)* likewise found substantial loss of sulfur dioxide during wine fermentation. However, Ingram *(9)* reported no substantial change in the total sulfur dioxide content during fermentation.

Rhan and Conn *(12)* reported that at high acidities sulfur dioxide is a good disinfectant and the effect of sulfur dioxide on yeast is due to the undissociated H_2SO_3 molecule and not ions. The different efficiency of undissociated molecules and ions was explained by the fact that it is difficult for ions to permeate living cell membranes.

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[a] Presented before the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 24, 1950.

[b] Published as Technical Paper No. 650 with the approval of the Director of the Oregon Agricultural Experiment Station.

Cruess *(3)* stated that sulfiting of wine in California was necessary to control wild yeasts and molds so that desirable fermentation with selected yeast cultures could predominate. He *(4)* advocates the addition of well above 350 p.p.m. sulfur dioxide for sweet California sauternes at the time of bottling. His theory was that the sulfur dioxide would decrease to below the legal maximum of 350 p.p.m. before the wine is sold.

To compensate the loss of free sulfur dioxide, winemakers have frequently added overdosages of sulfur dioxide to their wines, either in storage or during shipping. This results in both an undesirable taste and a violation of the law. Present Federal and most state laws allow 350 p.p.m. total sulfur dioxide in wine, regardless of its state, free or combined. Because of this regulation, and because only free sulfur dioxide is effective, it is to the winemaker's advantage to maintain a high free sulfur dioxide content in his wine, while staying within the tolerance of the law.

In order to maintain a high free sulfur dioxide content, frequent additions of sulfur dioxide in small installments either in the form of gas or bisulfite salts are recommended. This practice, however, is a nuisance for small batches of wine, and is particularly impractical during shipping. Some simple method that will maintain a free sulfur dioxide content continuously is, therefore, desirable.

Van der Plank *(13)* devised a method for regulating the release of sulfur dioxide in packages of stored table grapes. Suitable amounts of a mixture of dehydrated aluminum sulfate and sodium bisulfite were enclosed in packets of varying permeability. Evolution of the sulfur dioxide from the packets preserved the grapes.

EXPERIMENTAL

Some plastic materials, such as polyethylene film, are gas-permeable and reasonably moisture-proof *(1)*. Experiments showed that a small amount of fresh sulfur dioxide is given off continuously when sulfur dioxide, in the form of metabisulfite, is sealed in a polyethylene bag. It was found possible to maintain the free sulfur dioxide content by placing a polyethylene bag containing the metabisulfite in light sweet wines or dextrose solutions.

Experiments were conducted first on a laboratory scale, where regular wine bottles of 4/5-quart capacity were used as containers. Small polyethylene bags with an exposed surface area of 2 square inches were made from polyethylene film of 1/1000 of an inch thickness. Potassium metabisulfite was sealed in the bag in the amount of 200 parts of sulfur dioxide per million, based on the capacity of the bottle. This amounted to approximately 300 mg. of crystal potassium metabisulfite in each bag. The bags were heat-sealed and one bag was placed in each bottle. The bottles were then filled with 10 percent dextrose solution or light sweet wine, as the case may be, and stored in incubators at 86° F. (30° C.) and 99° F. (37° C.). Constant temperatures were used in the laboratory experiments, since the volatility of metabisulfite is related to the temperature. Comparatively higher incubator temperatures were employed, as they represent the temperature of warm days when wines require maximum protection.

The free sulfur dioxide content of each sample was determined at regular intervals for a period of 40 days.

For comparison purposes, experiments on the loss of total and free sulfur dioxide in light sweet wine were conducted under identical conditions. The permeability rate of sulfur dioxide through the polyethylene bag was also determined by placing the bag in distilled water.

RESULTS AND DISCUSSION

Figure 1 shows the loss of sulfur dioxide in light sweet wine stored at 86° F. (30° C.). The loss of total sulfur dioxide was gradual, but the loss of free sulfur

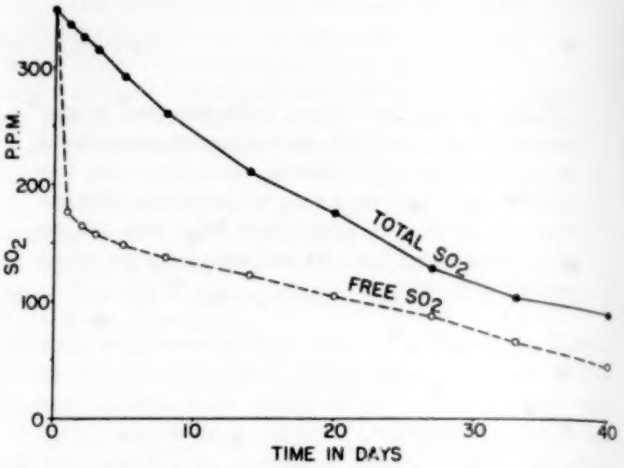

FIG. 1. Loss of sulfur dioxide in light sweet wine at 86° F. (30° C.).

dioxide was very fast during the first day, in fact, the first few hours. From then on, the free sulfur dioxide loss became gradual, with an average of 2 to 3 p.p.m. per day. Figure 2 shows a similar experiment at 99° F.

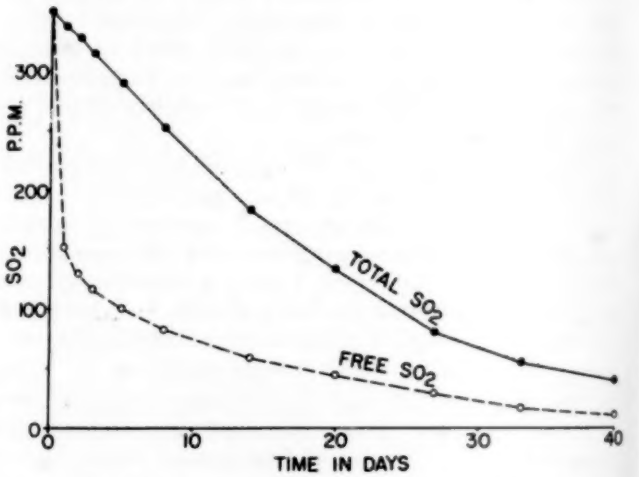

FIG. 2. Loss of sulfur dioxide in light sweet wine at 99° F. (37° C.).

(37° C.). The loss of both free and total sulfur dioxide was more rapid at this temperature, indicating that the sulfur dioxide loss in wine is related to the storage temperature.

Figure 3 shows the permeability rate of sulfur dioxide through the polyethylene film. The proportion of the metabisulfite to the water was 200 p.p.m., calculated as sulfur dioxide. Note that the permeability rate of sulfur dioxide is greater at 37° C. than at 30°, except that after 30 days the increase in concentration at 37° C. became very small. This was probably because the amount of sulfur dioxide remaining in the bag became too small to be of any significance, although, theoreti-

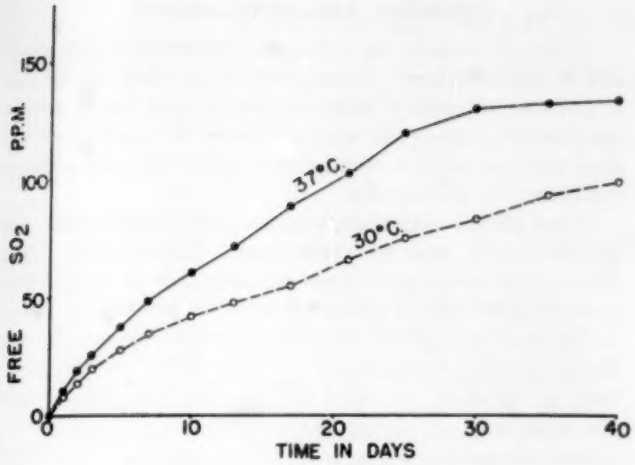

FIG. 3. Permeability rate of sulfur dioxide through polyethylene film.

cally, approximately 70 p.p.m. sulfur dioxide still remained in the bag.

Figure 4 shows the free sulfur dioxide content of 10 percent dextrose solutions stored at 86° F. (30° C.). At the start, both of these solutions had a free sulfur dioxide content of 146 p.p.m. The sample without the bisulfilte bag lost its free sulfur dioxide during the first few days only; after that, the free sulfur dioxide content remained more or less constant. At the end of 40 days, there was as much free sulfur dioxide in the solution as

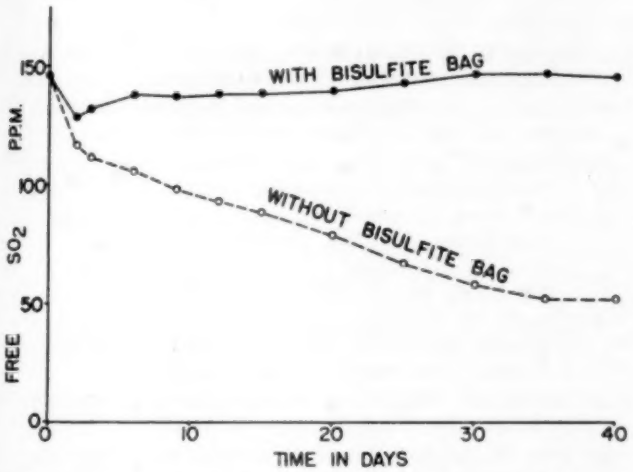

FIG. 4. Free sulfur dioxide content of 10 percent dextrose solutions at 86° F. (30° C.).

there was at the start. Figure 5 shows the same set of experiments with the storage temperature at 99° F. (37° C.). Although the loss of free sulfur dioxide was greater at this higher temperature, the same with the Bisulfite bag maintained its free sulfur dioxide content throughout the storage period. Evidently the higher permeability rate of sulfur dioxide through the polyethylene bag at this temperature had counter-balanced the higher loss of free sulfur dioxide.

Figure 6 shows the free sulfur dioxide content of light sweet wines stored at 30° C. At the start, both of these wines had a free sulfur dioxide content of 142 p.p.m. The sample without the bisulfite bag lost almost all of the free sulfur dioxide. After a loss which occurred in the first few days, the one with the bisulfite bag maintained its free sulfur dioxide content. At the end of the experiment there were still 90 p.p.m. free sulfur dioxide remaining in the wine. Note that the loss of free sulfur dioxide in light sweet wine was greater than that in the dextrose solutions; this indicates that dextrose is not the only compound combining with the free sulfur dioxide. Other substances, such as esters, alcohol, or acids, may all have a bearing on the loss of free sulfur dioxide.

At 37° C., the light sweet wine with the bisulfite bag likewise maintained its free sulfur dioxide content after

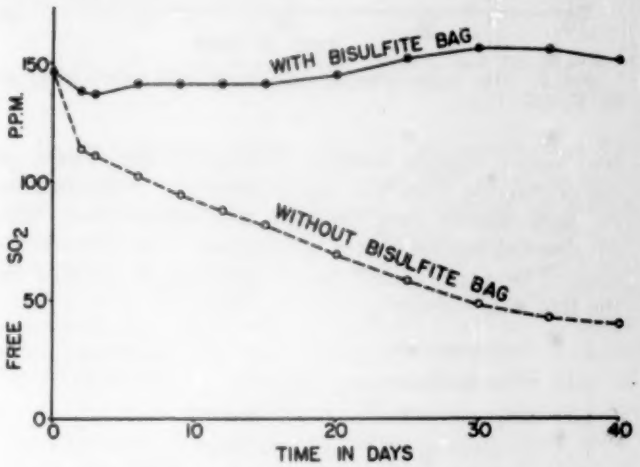

FIG. 5. Free sulfur dioxide content of 10 percent dextrose solutions at 99° F. (37° C.).

the first few days as shown in Figure 7. Note that at this temperature, the free sulfur dioxide content was maintained at 100 p.p.m. as compared with 90 p.p.m. in the 30° experiment. This can be explained by the higher permeability rate of sulfur dioxide at the higher temperature. This is a desirable phenomenon, since the wine requires more protection at high temperatures than at low.

Continuous agitation during storage of the samples containing the bisulfite bags showed no effect on the

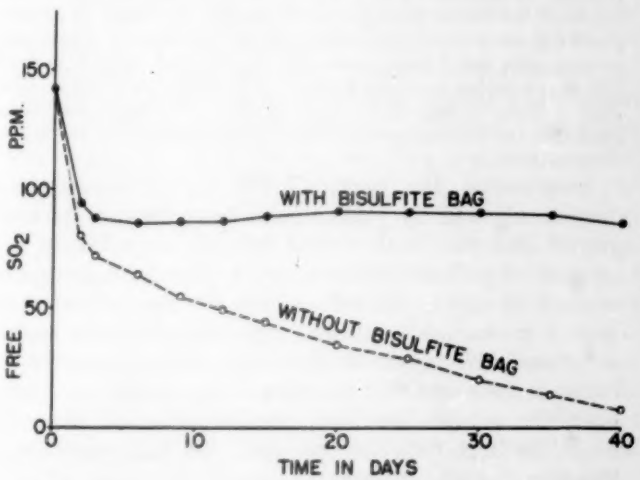

FIG. 6. Free sulfur dioxide content of light sweet wines at 86° F. (30° C.).

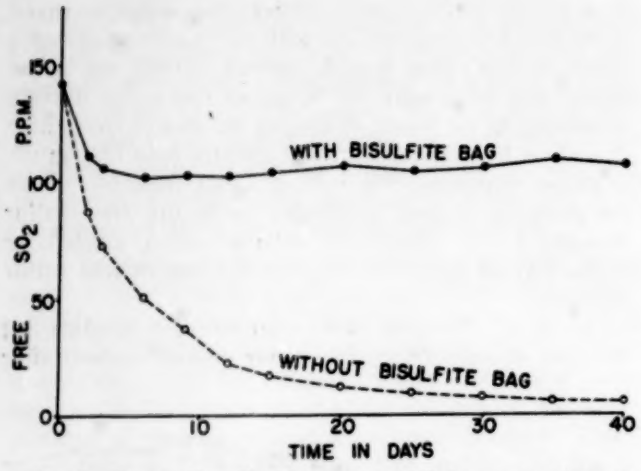

FIG. 7. Free sulfur dioxide content of light sweet wines at 99° F. (37° C.).

free sulfur dioxide content. Evidently the release of sulfur dioxide from the bag is primarily controlled by its permeability rate through the polyethylene film. Mechanical agitation does not increase this permeability rate. The permeability rate is probably controlled by the following factors:

(1) Temperature.
(2) Film thickness.
(3) Exposed surface area of the bag.
(4) Amount of bisulfite in the bag.

Attempts were made to determine the permeability rate of sulfur dioxide per square inch of exposed surface area. However, inconsistent results were obtained, probably due to too many variable factors involved. Thus, the size of the bag and the amount of the bisulfite to be sealed in each bag will have to be adjusted for each batch size of wine.

Further experiments were conducted in wineries, where 65 gallons of wine in barrels as well as 2000 and 3000 gallons in tanks were employed. Polyethylene bags of various sizes were made from film with a thickness of 1/1000 of an inch. Two bags, each with an exposed surface area of 24 square inches and each containing 2 ounces of potassium metabisulfite, were suspended in a 65 gallon barrel of wine. By so doing, it was found possible to maintain a free SO_2 content of approximately 100 p.p.m. in the barrel for a period of 30 days. In order to accomplish the same result for 2000 gallons of wine, it was found necessary to use 3 bags, each with an exposed surface area of 120 square inches and each containing 2 pounds of bisulfite. For 3000 gallons, 4 such bags were needed. The bags were suspended in the wine near the surface, where it requires the maximum protection.

Considering the limit of 350 p.p.m. total sulfur dioxide allowed by Federal and state laws, it is suggested that this limit should not be exceeded in the amount of sulfur dioxide added to the wine, plus the amount of sulfur dioxide placed in the polyethylene bag. For example, put 150 p.p.m. sulfur dioxide in the wine and 200 p.p.m. in the bag. This precaution is taken in the event that the plastic bag is broken. However, the polyethylene bag can be easily and securely sealed by heat. With proper care, the bags made from this film should not break.

SUMMARY AND CONCLUSIONS

Sulfur dioxide is the sole legal preservative for wine, and it has been used extensively to stabilize wines and to prevent secondary fermentation in light sweet wines, particularly during the warm seasons. A simple method that will maintain in wine a free sulfur dioxide content continuously is desirable.

Some plastic materials, such as polyethylene film, are gas-permeable and moisture-proof. Experiments have shown that when potassium metabisulfite is sealed in a polyethylene bag, it gives off a small amount of fresh sulfur dioxide continuously due to volatilization. It was found possible to maintain the free sulfur dioxide content, or, at least, to retard the loss, by introducing into the wine one, or several, polyethylene bags with the required exposed surface area and containing the proper amount of bisulfite.

ACKNOWLEDGMENT

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Chemical Agents and Residues in Foods: The Grower's Viewpoint[a]

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The grower uses chemicals for growing fruits, vegetables, and other crops for the purpose of controlling insects, diseases, and recently weeds. Without the application of these chemicals, our fruits and vegetables would be unacceptable to the consumer and there would be no fruit and vegetable industries. Approximately two hundred million dollars a year is spent for chemicals alone to protect the crops from insects and diseases.

The consumer, allowed choice in a free market, dictates and governs farm practice, determines our agriculture and the food we consume. The grower produces the products for the traditional market with such changes as current conditions and consumer preference from time to time demand. The consumer's choice is largely determined by personal desire, price, quality, convenience, and appearance. An agricultural industry that operates under a free economy, not restricted by governmental interference, price supports or production allotments has, in the past, and will, in the future, provide the consumer with better food supplies at less cost. Furthermore, this food will be of higher quality, better packaged, and more attractive, making for a continued higher standard of living. Today the consumer has a wide choice of all kinds of foods with many different degrees of processing, kinds of packages, of known quality and prices commensurate with the kind of food and the services rendered.

Forty years ago the industry known as the processing industry for fruits and vegetables produced only 15.2 lbs. of vegetables per person whereas today the consumer is buying over 36 lbs. of canned vegetables per person. At that time, there was no such thing as a baby food industry. Today it is one of the rapidly growing parts of the processing industry. Forty years ago the housewife made her own soup. Today she buys a large proportion of it canned, averaging over 7 lbs. per person. Forty years ago highly perishable vegetables such as lettuce, lima beans, asparagus, peas and broccoli were not available on most markets. Today no market would be complete without these vegetables. Forty years ago the packages were almost exclusively wholesale bushel, box, and barrel. Today the consumer's package has taken over much of the fresh fruit and vegetable industry as well as canned and frozen. Forty years ago, our insect problem was a minor matter whereas today practically no highly perishable crops are any longer grown without the use of chemicals for their protection from insects, and diseases.

Per Capita Consumption of Fruits and Vegetables Forty Years Ago and Now [a]

	Canned	Juice	Fresh
Vegetables, in 1909	15.2 lb.	.....	200 lb.
Vegetables, in 1949	36.4 lb.	.....	245 lb.
Fruit, in 1909	3.0 lb.	0.5 lb.	137 lb.
Fruit, in 1948	17.0 lb.	18.1 lb.	133 lb.

[a] From Agricultural Outlook, 1950, U.S.D.A. and Consumption of Food U. S. 1909-48, U.S.D.A. Misc. Pub. No. 691.

Fresh vegetable consumption has increased from 200 lbs. per capita in 1909 to 245 lbs. in 1949. For the same period, the per capita consumption of canned vegetables has increased from 15.2 lbs. to 36.4 lbs. In addition to this, we have recently developed a sizeable frozen foods industry that is supplementing both fresh and canned forms of marketing. Forty years in the food industry has maintained the per capita consumption of fresh fruits without any great change except for the kind of fruit the consumer selected. There has been a tremendous shift from apples to citrus. On the other hand, there has been a great increase of consumption of canned fruits ranging from 3 lbs. in 1909 to 17.0 lbs. in 1948. During this same period, a large industry has been developed in fruit juices. In 1910, less than ½ lbs. were consumed per person whereas in 1948, the figure was 18.1 lbs.

All of these changes have come about because of the freedom of choice of the consumer and the opportunity for the producer to supply this free market without governmental restrictions.

THE PURPOSE OF INSECTICIDE APPLICATION

Insects and diseases are a continual threat to the grower's crops. They injure the crop either by destroying the plant so that it will not produce the yield or by making the product undesirable from the viewpoint of the housewife because of the presence of the insects and diseases. Consumers will not buy apples with worms in them or apples that are partly decayed. It is true they have nutritional value but they are an unwanted product. The U. S. Department of Agriculture has stated that there are more than 80,000 insect species in the United States of which no less than 6,000 cause damage to crops. If we include the large number of plant diseases, we have a measure of the problem the farmer has in his efforts to grow a product that will meet the specifications demanded by the consumer. The farmer spends approximately $200,000,000 a year to protect his crops from insects and diseases. Much of this cost is not only to protect the crop from damage but to eliminate all disease and insects from the product before it goes to the processing plant or fresh market.

[a] Presented before the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 22, 1950.

For some crops, chemicals are one of the major items in the cost of producing the crop. I have personally known growers who spent more than $50.00 per acre not only to protect broccoli but more important to keep it free from insects when it is marketed.

Dr. F. C. Bishopp, Assistant Chief of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, at the recent Food and Drug Hearings, made the following statement:

"Wormy apples, berries, cabbage, maggot-infested peppers, wormy corn, celery, and other crops, would reach the market fit only for garbage disposal unless the insect pests are controlled. Standards set on insect contamination by market inspectors and Food and Drug officials are a guarantee that such foods will reach the consumer in reasonably good condition.

"This would not be possible without the use of insecticides. Many products now enjoyed by the American public would no longer be found in our markets. The fruits and vegetables of high quality now reaching the consumer are not accidental. They are available by virtue of carefully planned and executed control through the use of insecticides and fungicides."

SELECTING INSECTICIDES AND FUNGICIDES FOR THE PARTICULAR CROP AND INSECT

Long years of experience, guided by the findings and recommendations of our agricultural institutions along with those of the manufacturer and distributor, has established our present use of chemicals for crop protection. These are selected for the particular crop and insect or disease that is liable to attack the plant while growing. They are furthermore selected so as to leave the minimum amount of any objectionable residue or a residue that can be eliminated by washing before the product is sent to market. In addition, the grower prefers a chemical that is safe for human beings to handle, that has no undesirable odor, and if at all possible that is not toxic to warm-blooded animals. The timing of the application, the amount to apply, the method of applying and the diluent ordinarily used for the chemical have all been carefully tested by scientists from our agricultural institutions and the manufacturers of these chemicals. Inasmuch as these chemicals are applied to the fields adjacent to those where livestock frequently are pasturing, the farmer knows not only of the danger to himself and to his employees but also the danger to his livestock if he does not select the proper chemical, and if he does not use the chemical in keeping with the recommendations.

Today the many new insecticides developed during and since World War II are adding many new problems to the grower's responsibility. The proper farm practice must be established for each selected insecticide and crop. The food processor must have a much broader understanding of insecticide uses and the dangers of residue for each particular crop and insecticide used. Federal, State and local health agencies have a responsibility of guarding against toxic residues left on foods.

AN APPRAISAL OF PRODUCERS

There are four definite types of fruit and vegetable growers who use chemicals in keeping with their own ideas and needs.

First, the Home Gardener. This producer usually is more liberal in the use and application of chemicals than either the market gardener, the truck crop producer, or the good processor. Since home gardening is not wholly an economic enterprise, the gardener does not restrict himself in cost, and he frequently harvests the crop with liberal amounts of residue.

The market gardener and the truck crop producer are governed largely by the consumer's demands and the cost of chemical control of pests. These operators are well equipped for the application of chemicals and also for the elimination of residues by washing, if necessary.

The same applies to the fruit producer. He is meticulous in the selection, timing, method of application, and the removal of residue from his products before it goes to the market.

The food processor, on the other hand, should not only be a scientist but also a diplomat and psychologist. He must know when he receives his product for processing what chemicals have been used for the control of insects and diseases, when they were applied, and if any residues remain, how they can be removed. He knows that some chemicals leave residues of odor and taste that are impossible to remove. Furthermore, these particular qualities are accentuated with time. The product may be purchased without any noticeable odor or flavor. Later these qualities may be quite pronounced. Of all the producers and marketers of perishables, the food processors must be, and are, the most exacting. The familiarity of the processor with this situation, together with the greater task imposed by newer chemicals, is creating interest on the part of the food technologists in this important field of the food industry.

A FIELD FOR THE FOOD TECHNOLOGISTS

Perishable fruits and vegetables marketed in different forms represent a farm value of approximately 2.3 billion dollars. It nicludes 36 percent of the tonnage of food consumed. The use of chemicals for protecting these crops from insects, diseases and to a lesser extent, weeds, is essential. It represents 22 percent of the total value of farm crops. It is one of the major food items that is essential for a good diet of which more should be consumed for better health.

Approximately 1,700,000 acres of vegetables were grown for the fresh market and 1,700,000 acres for the processed market in 1949. This includes only 25 of the most important crops for the fresh market and 11 for the processed market. Large quantities of additional vegetables are grown by the small market gardener and the home gardener. We can add to this the acreage of bearing fruits, somewhat over 2,000,000, which in 1949 produced over 15,000,000 tons for the fresh and processed markets.

Volume and Value of the 1949 Fruit and Vegetable Industry

	Value	Tons
Fruit (except dried)	$ 791,252,316	14,557,300
Truck Crops	589,757,000	8,186,200
Potatoes	563,508,000	12,058,860
Sweet Potatoes	115,843,000	1,491,380
Vegetables for Processing	206,144,000	5,522,610
Total	$2,266,504,316	41,816,350

The retail value of fresh fruits and vegetables is estimated by the U. S. Department of Agriculture to be two and one half times that of its farm value. When processed, it is approximately four times the farm value. The grower delivers his fruit and vegetables to the processor in bulk without washing, grading or packaging. Hence, farm value is less than when prepared for fresh market.

A food technologist has an interest in the economics of this industry. When costs of marketing become excessive, other methods must be found or the consumer will select foods with greater value for dollar expended. The requirements for chemicals to control insects and diseases is not only a costly burden to the grower for materials but also entails large costs of labor and equipment. In addition to this, the grower must be well equipped with technical information necessary for selecting and applying these chemicals and keep a continual check on its controls. Many processors are employing trained entomologists and pathologists to work with the growers. It is their duty to furnish the growers with the information of the kind of chemicals to use and when and how to use them. Without such controls, the crops delivered by growers to the processing plant would be unfit for processing. They would not be free from disease and insects and they might not be free from undesirable residues. The crops delivered to the processing plant are not only grown under the processor's direction and observation but also subject to biological and chemical tests to check on the presence of any insects or diseases as well as possible residue. Many growers for the fresh market have installed equipment for washing fruit and vegetables for the purpose of making them more attractive in appearance and eliminating any residues that may remain from chemical treatments. The food technologist should be familiar with the practices necessary to grow and deliver quality fruits and vegetables, free from insects, diseases and unwanted residues. He should have a close acquaintance with the entomologist, pathologist and grower practices.

TOXIC PROPERTIES OF CHEMICALS USED ON FRUITS AND VEGETABLES

There is no record of the number of laboratories engaged in studying toxicity of agricultural chemicals. Some workers in this field estimate the number to be approximately 25. Some of these laboratories are maintained by the manufacturer of these chemicals, others by our agricultural institutions. There are, in addition, a few consulting laboratories active in this field. The U. S. Department of Agriculture and the Food and Drug Administration are fully aware of the importance of this work. They not only participate in the work itself but they are active in coordinating the results so the grower can make the most intelligent selection with the least hazard to all concerned. Some workers estimate that there are 500 to 1,000 or more products receiving some study each year. Most of these are quickly eliminated. The few remaining are given a much more thorough and extensive investigation for a number of years until their toxicological properties have been well tested. The policy of most manufacturers of new chemicals is to determine their toxicological properties very early in this process. Their margin of safety must be established at each step throughout the development of the chemical itself from manufacturer to application and residue left on the product to which it is applied.

The first insecticides were composed mostly of arsenic. This type of insecticide was extremely toxic to warm-blooded animals but have been now largely replaced. Today we have substituted insecticides that are much less toxic to human beings and warm-blooded animals. The arsenics were followed by nicotine, rotenone and pyrethrum. They are very effective on a large number of insects and are not so toxic to human beings or warm-blooded animals. An overdose can cause temporary discomfort but would not as ordinarily used be at all fatal except in the case of nicotine.

We are now bringing into use a large number of organic insecticides that are highly specific and oftentimes very erratic when used without understanding and experience. The organic phosphorus compounds are very effective for control of insects such as aphids and mite whereas the chlorinated compounds are more frequently used as an insecticide for control of lepidoptera (worms). They are selective and control the large crawling insects. They are less toxic to warm-blooded animals than the arsenics and much safer to use. Nevertheless they present a greater risk than insecticides such as rotenone and pyrethrum. Safety demands they must be carefully screened and tested not only for the toxic properties but also for the residue left in soil as well as that on the crop itself. On the whole, however, products such as D.D.T. have had a good record. This is the most commonly used chlorinated insecticide. Its common use was quickly accepted because of the necessities from war. There are others of the newer insecticides, however, that have proved themselves hazardous for employees in their manufacture and application to the crop. Many residues, left on the plant, oxidize in a relatively short period of time. Consequently the welfare of the consumer is not endangered.

FUNGICIDES

The fungicidal development for plant disease control began with the use of sulphur, copper and lime. Others have been added from time to time, such as organic mercury, fixed coppers and many organic fungicides. With the introduction of the latter we now have many specific fungicides for certain diseases and plants. These organic fungicides are much less toxic to warm-blooded animals and usually safer to use on the plants themselves. Fungicides have, for many crops, fully as important a role for producing good, sound, attractive fruits and vegetables as insecticides.

SOME REGULATIONS

In a democratic government, we establish laws and rules of fair play for the protection of the individual. Though the consumer demands that the grower supply him with a product free from insects and diseases, fresh and attractive in appearance, packaged for his convenience, at a price that he can afford to pay, he still

must have the product free from any injurious chemical. This is a sizeable order. For the purpose of meeting this situation our government is holding hearings in which over 100 scientists from the United States and Hawaii have appeared and over 60 entomologists have been present. Directors of Experiment Stations, U. S. Department of Agriculture scientists and representatives of major farm organizations have all appeared and testified on the necessity of using chemicals to produce these crops. Without them we would have no fruit and vegetable industry. Industry representatives have also given testimony. Fifty fruits and 50 vegetables have been included in this discussion with the listing of most all of the insecticides and fungicides used commercially. It is hoped that out of this mass of information we can arrive at a recommended procedure that will be practical and safe for the industry in all its phases from producer to consumer. The use of chemicals not only includes the control of insects and diseases but also the control of weeds and it may be when we learn more about the use of hormones that they will take a front rank in this same group.

Studies on the Peroxidase in Pickles and Pears[a]

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Studies to determine the effect of various concentrations of a peroxidase preparation on the quality of processed packs of pureed cucumber pickles stored at various temperatures have been continued. The presence of peroxidase was found to play a role in lowering the quality of the color, flavor and aroma of processed cucumbers. The effect on quality was more noticeable with samples containing the greater concentration of peroxidase.

The peroxidase activity in fresh pears as measured during various stages of maturity varied considerably. The activity was greatest during the very green and ripe stages of maturity, and decreased markedly from the ripe to over-ripe and rotten stages. The significance of these observations is discussed.

Processing conditions as used for the destruction or inhibition of microorganisms capable of producing deterioration in a variety of commercial fruit and pickle products were also adequate to insure complete inactivation of the peroxidase system in those foods with the exception of packs of Kosher style dill and processed dill pickles.

Previous studies by Kaplan, Esselen and Fellers *(9)*, and Nebesky, Esselen, Kaplan and Fellers *(14)* showed that the processing times necessary to inactivate the peroxidase system of canned acid foods at specific temperatures could be predicted, and that the calculated process times were in good agreement with observed process times. They also indicated that considerable variation in thermal stability of peroxidase occurs within different packs of the same product, and that this difference may be attributed to the peroxidase concentration in the product. Peroxidase which was not inactivated in fresh cucumber pickles during processing was not destroyed during storage for one year.

From the many studies on the inactivation of enzyme systems of fruits and vegetables prior to freezing or dehydrating, it has been noted that destruction of enzymes frequently seems to parallel quality improvement. The thermal inactivation of catalase in some vegetable tissues occurs at a rate closely parallel to inactivation of the enzyme concerned in the development of off-flavors. Diehl, Dingle and Berry *(3)* found that Alderman peas scalded at various temperatures long enough to inactivate catalase did not form undesirable odors and did not change in color when stored at 20° F. (—6.7° C.) for four months. In investigations by Joslyn and Bedford *(6)* and Joslyn and Marsh *(7)*, peroxidase activity paralleled off-flavor formation more closely than did catalase activity, but this correlation varied markedly with the nature of the substrate used for detecting peroxidase activity. The works of Joslyn and Marsh *(8)*, Kertesz *(10)*, Woodroof and Atkinson *(16)*, and Zilva *(17)*, likewise have emphasized the importance of enzyme systems in the deterioration of acid foods.

In view of the above facts and inasmuch as the evidence obtained in preliminary studies has indicated that the presence of peroxidase may persist in processed products such as fresh cucumber pickles, it was considered possible that the enzyme was responsible for deteriorative changes in color, flavor, and aroma of these products during storage. Therefore, it was decided to investigate further the stability of peroxidase in fresh cucumber pickles with attention focused particularly on its effect on quality of this product.

EXPERIMENTAL

Effect of Peroxidase on the Quality of Processed Cucumber Puree

This phase of the investigation was carried out to determine the effect of various concentrations of a peroxidase preparation on the quality of processed pureed cucumber pickles during storage at different temperatures.

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[b] Presented at the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 24, 1950.

Packs were prepared by adding a weak brine solution, 20 percent by weight, to the fresh, washed cucumbers and mixing in a Waring Blendor for five minutes. The brine solution, pH 3.2, was made up from 36 fluid oz. of 4 percent vinegar; 92 fluid oz. of water; 7 oz. salt, and water to make one gallon.

The pureed pickles, pH 4.1, were then filled into 25-ml. vaccine-type serum bottles by means of a 50-mm. syringe and a 15-gauge needle leaving a 10 percent headspace. The bottles were sealed with sleeve-type, self-sealing rubber stoppers of the type used for serum and containing a depressed central area for introducing the needle. The mixture was filled in at room temperature and processed in a boiling water bath for 30 minutes, removed, cooled, and inoculated with a relatively purified concentrated peroxidase extract obtained from the same lot of cucumbers used to put up the pack. The experimental pack was divided into 3 lots consisting of 12 bottles each. One lot was inoculated with a purified peroxidase extract of such strength that the final pack contained a concentration of peroxidase equivalent to that in the fresh cucumber. The second lot was inoculated with a peroxidase extract of such strength that the final pack contained a concentration of peroxidase 50 times greater than that found in the fresh cucumber. The third lot was used as the control. Samples were stored at 35° F. (1.5° C.) and 100° F. (37.5°C.) for a period of 6 months.

Extracts of the purified concentrated peroxidase solution were obtained using the method previously described by Nebesky, et al. *(14)*. In order to obtain a peroxidase extract of such strength that when inoculated into the experimental packs the resulting concentration would be equivalent to the concentration in the original cucumber, it was necessary to extract all of the enzyme from an equivalent weight of the product ed to put up the packs. The weight of cucumber representing 1 lot, or 12 bottles, was approximately 250 g. Thus, for lot 1, a 250 g. sample of unpeeled cucumbers was prepared as previously mentioned and the final peroxidase precipitate suspended in 12 ml. of phosphate buffer which had been previously sterilized in an autoclave at 250° F. (121.1° C.) for 30 minutes. The precipitated peroxidase was transferred aseptically from the ethanol, which was sterile, to the buffer solution thereby obtaining a relatively purified concentrated sterile peroxidase extract. For lot 2, a 12.7 kg. sample of unpeeled cucumbers was prepared in a manner similar to the above except that the final peroxidase precipitate was suspended in 24 ml. of sterile phosphate buffer. This 12.7 kg. sample corresponded to a weight 50 times greater than the weight of the product representing 1 lot. The final peroxidase solution was of such a concentration that, when inoculated into experimental packs, it corresponded to a concentration approximately 50 times greater than the amount of enzyme in the original cucumbers.

Inoculation of processed packs of pureed cucumbers with the respective sterile concentrated enzyme extracts was carried out aseptically with a sterilized syringe. Each cucumber pack of lot 1 was injected with a 1-ml. portion of the respective purified peroxidase preparation. A 2-ml. portion of the second purified peroxidase extract was injected into each pack comprising the second lot.

The concentration or degree of peroxidase activity was determined on the original and dilutions of the original representative samples. The measurements were performed colorimetrically, as described by Morris, Weast, and Lineweaver *(11)*, by measuring the total color formation in the Evelyn Photoelectric colorimeter at the end of an incubation period of 30 minutes. The galvanometer readings obtained with the test sample were a measure of peroxidase activity. The galvanometer was first adjusted to 100 with an enzyme-inactivated control. The No. 420 filter was used in the colorimeter for these determinations. The results obtained showed the concentration of peroxidase, on the basis of peroxidase activity, to be approximately equal to, and 50 times greater than, the concentration of this enzyme in the fresh cucumber, in packs representing the first and second lots respectively (Table 1).

Packs were stored in the dark, at the temperatures mentioned above, for a period of 6 months. At each successive 2-month interval, representative samples, comprising a composite of two bottles, were examined as to color, flavor, aroma, and appearance.

TABLE 1

Concentration or Degree of Peroxidase Activity as Determined Colorimetrically on Samples Obtained from Inoculated Packs

Sample	Percent Transmittance [c]
Fresh cucumber	68
Lot No. 1.	
Concentration of peroxidase equivalent to concentration in fresh cucumber	71
Lot No. 2.	
Concentration of peroxidase 50 times greater than concentration in fresh cucumber	3
Lot No. 3.	
Sample diluted with distilled water 1-49	72

[c] Determined colorimetrically. High readings indicate slight activity; low readings, indicate high activity.

RESULTS

The results of this study represent a storage period up to 6 months (Table 2). The findings indicate that the presence of a peroxidase preparation did play a role in lowering the quality of the color, flavor, and aroma of processed cucumber packs. The effect on quality was recognized by the development of a distinct flat or hay-like flavor and aroma, along with a bleaching or fading

TABLE 2

Effect of Various Concentrations of Peroxidase and Two Storage Temperatures on the Quality of Processed Cucumber Pickles

Concentration	Color	Odor	Flavor	Peroxidase Acivity [d]
Storage for 2 months at 35° F. (1.5° C.)				
Control	good	good	good	100
Concentration equal to that in fresh cucumber	slightly lighter	good	good	70
Concentration 50 times greater than that in fresh cucumber	slightly lighter	slightly flat	slightly flat	3
Storage for 2 months at 100° F. (37.5° C.)				
Control	good	good	good	100
Concentration equal to that in fresh cucumber	slightly lighter	good	good	70
Concentration 50 times greater than that in fresh cucumber	slightly lighter	slightly flat	slightly flat	4
Storage for 6 months at 35° F. (1.5° C.)				
Control	good	good	good	100
Concentration equal to that in fresh cucumber	much lighter	slightly flat, hay-like	slightly flat, hay-like	67
Concentration 50 times greater than that in fresh cucumber	very much lighter	very flat, hay-like	very flat, hay-like	3
Storage for 6 months at 100° F. (37.5° C.)				
Control	good	good	good	100
Concentration equal to that in fresh cucumber	lighter	slightly flat, hay-like	slightly flat, hay-like	68
Concentration 50 times greater than that in fresh cucumber	much lighter	flat, hay-like	flat, hay-like	3

[d] Higher readings indicate slight activity; low readings indicate high activity.

of color. This deterioration was more noticeable with samples containing the greater concentration of peroxidase, and with samples stored at the lower temperature. Of interest was the fact that packs stored for six months at the lower temperature, 35° F. (1.7° C.), showed a greater loss of quality than similar packs stored for the same period at 100° F. (37.5° C.). This observation suggests a number of possible explanations. Although it is recognized that within certain temperature limits the velocity of enzyme activity is increased by a rise in temperature until an optimum temperature is reached, further increase in temperature causes a decrease in velocity until the inactivation temperature, at which the enzyme is rapidly destroyed, is attained.

The optimum temperature for most enzymes has been reported to lie between 104° and 122° F. (40°-50° C.), but there are a number that have a temperature optimum in the neighborhood of 140° F. (60° C.). Reddi, Esselen, and Fellers *(15)* found that the maximum activity of guaiacol peroxidase of apple tissue was obtained at 86° F. (30° C.), o-phenylenediamine peroxidase activity at 104° and 122° F. (40°-50° C.), and pyrogallol peroxidase at 120.2° and 122.0° F. (49°-50° C.). However, it is suggested that the temperature optimum for enzymes may be a misconception since the results obtained depend, as it is now commonly known, on the length of the period of determination.

Joslyn *(5)* suggested the possibility that enzymes differ in their power to survive prolonged exposure to low temperatures, and changes in the enzyme systems by partial destruction of the more labile enzymes, such as the dehydrogenases, may alter the type as well as the rate of chemical change produced. Another possibility is the formation or accumulation of intermediates brought about by refrigeration which could produce an imbalance in the chain of enzyme reactions. Further, in any definition of optimum temperature, experimental conditions in respect to pH values, as well as concentration of enzyme and substrate must be specified.

Although the peroxidase extract obtained in this investigation exhibited strong peroxidase activity, other enzyme systems such as polyphenolase, catalase, phosphatase, ascorbic acid oxidase, and pectinase, which are known to occur in the raw material, were undoubtedly present since the purification of an individual enzyme system would involve a much more complicated technique than that used in this investigation. Therefore, the deterioration in the above processed packs may have been due to the cumulative effect of peroxidase and other enzymes. However, the high thermostability of peroxidase in comparison with other enzyme systems suggests the possibility that this enzyme alone may survive the heat treatment and be responsible for deterioration in processed foods.

EFFECT OF MATURITY ON PEROXIDASE ACTIVITY

Subsequent studies have revealed that the concentration or distribution of peroxidase varied within different lots of the same products. One factor responsible for this variation may be maturity. Bailey and McHaugue *(2)* found that catalase and peroxidase activities declined regularly as tomato fruits ripened. In leaves, catalase, peroxidase, and invertase activities increased with increasing maturity and decreased with the onset of senescence. Oxidase activity was at a maximum in the longest leaves and declined as the leaves developed. Likewise, the studies of Naito and Isimaru *(12)* showed that the activity of ascorbic acid oxidase in grapes, peaches, cucumbers, and eggplant decreased with ripening. Ivanov *(4)* observed that the enzyme activity of the fruit of pumpkin diminishes with the progress of ripening. When this ripening was artificially stimulated by means of ethylene, the enzymatic activity had ceased altogether. In their studies on wheat grain, Bach, Oparin, and Vener *(1)* mentioned that the activity of catalase, peroxidase, amylase, and protease at first increased irregularly, reached a certain maximum, then dropped more or less abruptly in the course of ripening. The studies of Naito, et al. *(13)*, and many others revealed that the activity of enzymes does vary according to the degree of ripeness.

In view of the above reports, a study was initiated to determine the relationship between maturity and peroxidase activity of fresh pears. The degree of peroxidase activity was determined in representative samples of the fresh fruit at various stages of maturity from very green (immature) to ripe, over-ripe, and decayed (excessively over-mature). Investigations were also made to determine the relationship between degree of maturity and peroxidase activity on samples during storage at 70°-80° F. (21.1°-26.7° C.) and 35° F. (1.5° C.). Samples were prepared and assayed for peroxidase activity by a method similar to that previously employed using guaiacol as the substrate.

The data obtained on fresh pears showed that the peroxidase activity varied considerably during various stages of maturity, decreasing with increased maturity of the fruit. This activity was greatest when the pears were very green and decreased only slightly up to the ripe stage. It decreased markedly from the ripe, to over-ripe, and excessively over-ripe stages. The results obtained from determinations of peroxidase activity of fresh pears allowed to ripen during storage at 70°-80° F. (21.1°-26.7° C.) and 35° F. (1.5° C.) are shown in Table 3. With samples stored at the higher temperature, the variation in peroxidase activity during the

TABLE 3

Effect of Maturity on Peroxide Activity of Fresh Pears During Storage

Degree of Maturity	Storage time	Storage temperature	
		70-80° F. (21.1-26.7° C.)	35° F. (1.5° C.)
	days	*Percent Transmittance* *	
Immature	1	3.5	1.0
	2	4.5	....
	3	4.5	1.0
	6	....	1.5
	10	....	2.5
Ripe	4	6.5	....
	5	7.5	....
	6	8.5	....
	14	....	3.0
	18	....	4.5
	22	....	6.0
	26	....	7.0
Over-ripe	7	20.0	....
	8	31.0	....
	9	76.0	....
	30	....	15.0
	34	....	22.0
	38	....	30.0
	42	....	38.0
Excessively over-ripe	10	56.0	....
	11	64.0	....
	12	66.0	....

* High readings indicate low activity; low readings indicate high activity.

ripening was more significant than with samples stored at 35° F. (1.5° C.), because of the increased rate of maturing at the higher temperature. In the former case the fruit matured from the very green to excessively over-ripe stages within a period of 12 days, while in the latter it required 6 weeks for the fruit to ripen from very green to the over-ripe stage. Maturity of the pears was determined by visual and organoleptic examination as to color, firmness of texture, and taste.

The data obtained are of interest since earlier studies revealed that the thermal destruction time for the peroxidase of various foods increased with increased concentration of the enzyme.

PEROXIDASE ACTIVITY IN COMMERCIALLY PACKED FOODS

This study was concerned primarily with determining the extent of peroxidase activity in a number of commercially packed, acid foods to ascertain whether the processing conditions for these products were sufficient to insure destruction or inhibition of the enzyme systems. Peroxidase was again selected because of its high thermostability. Furthermore, the inactivation of peroxidase would insure the destruction of any other known enzyme systems which are present. A variety of canned fruits (apples, apricots, peaches, pears, and fruit cocktail) and a number of cucumber pickle products (Kosher style dill, processed dill, sweet mixed, mustard, midget, chow chow, candied sticks, picklestix, and picallilli), obtained from the shelves of local markets and representing a number of manufacturers were investigated. In order to extend the results obtained in this initial study, the investigation was repeated after an interval of approximately 18 months on similar samples of commercially packed foods. These were obtained from the same source and represented the same manufacturers.

Representative samples of products, obtained from the zone of slowest heating in the respective jars, were assayed for guaiacol peroxidase. The procedure used was similar to that already described, and the development of color as noted visually was taken as indicating the presence of peroxidase activity. These studies revealed that the commercial processing conditions of time and temperature as used for the destruction or inhibition of microorganisms capable of producing deterioration were also sufficient to insure the complete inactivation of the peroxidase system in these foods with the exception of packs of Kosher style dill and processed dill pickles. The peroxidase was observed to be highly active in representative samples obtained from packs of Kosher style dill pickles and moderately active in samples obtained from packs of processed dill pickles. Subsequent determinations with various brands of these two products likewise revealed the presence of peroxidase. It may be concluded, therefore, that in the case of these two products the commercial processing conditions, although apparently adequate to inactivate the microorganisms, were not sufficient to insure complete inactivation of the peroxidase system. Further, it can be assumed that if the peroxidase was not destroyed other enzyme systems might likewise retain their activity during processing and become capable of affecting the quality of such foods.

Whether the presence of these enzyme systems is harmful to food quality is difficult to predict, but, since previous studies revealed that peroxidase plays an important role in lowering the color, flavor, and aroma in pureed cucumber packs, one may look upon the presence of enzymes in foods as being potential spoilage agents.

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The Control of Browning in Frozen Sliced Apples[a]

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The control of browning in frozen apple slices was investigated. The effectiveness of mixtures of pectin, ascorbic acid, and various concentrations of sodium sulfite is discussed.

The problem of freezing apple slices for the bakery trade has interested research workers in the field of frozen foods for some time. In 1933, Joslyn and Mrak *(8)* made a study of the use of sulfites and sulfurous acid in the preparation of fresh and frozen fruit for baker's use and found that browning could be prevented by dipping apple slices prior to freezing into an aqueous solution of 3000 to 4000 p.p.m. of sulfur dioxide or the equivalent amount of sodium sulfite. Tressler and DuBois *(10)* recommended the blanching of apple slices in flowing steam, followed by cooling as a treatment for apple slices to be frozen. Lee *(9)* reviewed the methods for the treatment of apple slices previous to freezing, and recommended steam blanching as the method most likely to yield the best product. The reason for this choice was the freedom from foreign flavors of the steam-blanched product as contrasted with the slight residual sulfur dioxide flavor in the apple slices treated with either sulfur dioxide or sodium sulfite after the product was made into pies, baked, and served. At the same time a method in which a dipping solution of sodium bisulfite was used in a concentration equivalent to from 2000 to 3000 p.p.m. of sulfur dioxide was recommended *(11)*. In this latter process a delay of at least 8 hours was recommended between dipping and freezing in order to permit the sodium bisulfite to penetrate throughout the slices.

Bauernfeind and Siemers *(3)* described methods involving the use of ascorbic acid in the packing of frozen apple slices. Bauernfeind, Smith and Siemers *(4)* described rather completely methods recommended for freezing julienne slices, flat slices, and sectional slices. The methods recommended involved the use of salt and ascorbic acid, and of a vacuum process. Dry sugar or sirup were also employed.

Cowgill *(6)* obtained a patent on the use of non-acid pectin in non-hydrated, non-gelatinous condition with fruit products for freezing. Baker *(2)* studied the use of pectin as applied to the freezing of strawberries and obtained an improved thawed product from its use. The same method was tried on peaches but the contradictory results obtained were thought by him to be caused possibly by varietal differences. High methoxyl pectin was found to be best for yellow peaches. Buck, Baker, and Mottern *(5)* reported the retarding of browning of peaches treated with pectin prior to freezing.

EXPERIMENTAL

In 1946, a number of samples of Rhode Island Greening, Baldwin, Northern Spy, and McIntosh apples were peeled, cored, and cut into slices of not over ½ inch thick. These slices were treated in the following manner:

1. Blanching for 90 seconds in flowing steam. They were then cooled in cold water, drained, frozen, and stored at 0° F. (—18° C.). This treatment prevented browning. 2. Immersion for five minutes in a solution of 4000 p.p.m. of sodium sulfite at room temperature. After immersion, the drained slices were held for three hours before freezing. This treatment prevented browning. 3. Immersion for ten minutes in a solution containing 400 p.p.m. of sodium sulfite, 0.25 percent low-ester (low-methoxyl) pectin 320[b] and 0.05 percent ascorbic acid.[c] After immersion, the slices were held for three hours before freezing. Only insignificant browning was noticed.

Other formulas tried gave only partial control of browning. In the presence of the low-ester pectin, all treatments showed better protection from browning.

This work was repeated in March, 1947, to determine whether 150 grade pectin would serve as well as the low-ester pectin used previously, and to determine the effectiveness of varying proportions of ascorbic acid and sodium sulfite. These tests were run only with Rhode Island Greening and McIntosh apples.

The solution found to give a product of the highest quality contained 600 p.p.m. of sodium sulfite, 0.2 percent of 150 grade pectin, and 0.05 percent of ascorbic acid. The slices were immersed for 5 minutes before draining and packing. They were then held for 3 hours before freezing and storing at 0° F. (—18° C.). The same solution without ascorbic acid or with the pectin omitted was less effective in controlling browning.

In 1948, another experiment was run, using Rhode Island Greening, Northern Spy, and McIntosh apples. The solutions used for the processing of these apple slices are given in Table 1, along with the results of the organoleptic tests on the apples in pies freshly baked from the lots of stored apple slices.

The frozen apple slices after 4 months' storage at 0° F. (—18° C.) were thawed only sufficiently to break apart and were made into 7-inch pies under uniform conditions, packaged unbaked in cellophane and stockinette, and immediately frozen and stored at 0° F. (—18° C.). Lot I-V was used after 11 months' storage. Half of the pies were baked and organoleptically tested after 3 months' storage and the other half after 7 months' storage. The scores used in evaluating the apples in the pies are given in Table 2. The results for the two pie storage periods were similar and therefore only the average scores obtained on the freshly baked pies of the 7 months' storage samples are given in Table 1. The panel consisted of 8 judges.

DISCUSSION

The freshly baked frozen pies prepared from the apple slices which had been previously stored for three

[a] Approved for publication by the Director of the New York State Agricultural Experiment Station as Journal Paper number 832.

[b] Kindly supplied by the General Foods Corporation, Hoboken, New Jersey.

[c] Kindly furnished by Chas. Pfizer and Company, New York.

TABLE 1

Effect of Pretreatment of Frozen Apple Slices on Their Palatability in Freshly Baked Pies

Code	Variety of Apple	Pretreatment [a]	Average Scores				
			Texture	Flavor		Retention of Shape of Slices	Total Score
				Aroma	Taste		
1-A	Greening	Steam blanched 1½ min., cooled and drained	8	14	24	15	61
1-F	Greening	Immersed for 10 min. into a solution containing 0.4 percent of ascorbic acid; 0.5 percent 150 grade pectin, and Na_2SO_3 to equal 400 p.p.m. of SO_2	6	14	27	13	60
1-1	Greening	Same treatment but 0.25 percent pectin used	5	14	28	13	60
1-V	Greening	Immersed for 10 min. into a solution containing 0.2 percent ascorbic acid; 0.25 percent pectin, and Na_2SO_3 to equal 800 p.p.m. of SO_2	3	14	22	9	58
2-A	Northern Spy	Steam blanched 1½ min., cooled and drained	9	14	23	15	61
2-F	Northern Spy	Treatment as in sample 1-F	6	15	32	14	67
2-1	Northern Spy	Treatment as in sample 1-1	7	14	31	14	66
3-a	McIntosh	Steam blanched 1½ min., cooled and drained	3	14	27	6	50
3-F	McIntosh	Treatment as in sample 1-F	2	14	30	5	51
3-1	McIntosh	Treatment as in sample 1-1	2	14	29	5	50

[a] Packaged, allowed to set for three hours before freezing. Stored at 0° F. (—18° C.) except the steam blanched samples which were frozen immediately after packaging.

TABLE 2

Method Used for Scoring Apples in Apple Pies

Quality factor	Score
Texture:	
Mushy	2
Soft	6
Firm	10
Tough	6
Rubbery	2
Flavor and Aroma:	
Pleasant	15
Unpleasant	5
Taste:	
Very good, natural	40
Good	30
Fair	20
Poor	10
Retention of shape of slices:	
Good	15
Fair	10
Poor	5
Total possible score	80

months received scores that were quite high except those for the pies with the McIntosh variety. These latter pies were scored low mainly because of failure to retain texture and shape of slices. This difficulty with cooked McIntosh apples has been known for some time.

The frozen pies baked after seven months' storage received scores that were in quite good agreement with those received after three months' storage. The only total score that showed a significant drop was that for Lot I-V Greening. This difference was the result of a drop in the scores for texture, flavor, and retention of shape of slice. It is quite likely that these changes were partially, at least, caused by the long period of storage. The flavor was affected by the residual sulfur dioxide content resulting from the use of high concentrations in the dipping solution. However, this was necessary to control the browning.

In preliminary tests with pies baked with apple slices that had been treated by dipping in 4000 p.p.m. of sulfur dioxide in the form of sodium sulphite, it was found that very low average scores were given this lot. On account of the detrimental effect of this high concentration of sulfur dioxide on the scoring abilities of the tasters, this lot was omitted from further taste tests. The judges scored these pies as definitely unacceptable both as to flavor and odor of the hot pie. The variety of apple used had no influence on this result.

It is obvious that the quantities of ascorbic acid used would tend to make the cost rather high.

It was found that both the low-ester pectin and the 150 grade pectin were effective under the conditions of the experiment in reducing the browning of the thawed apple slices. This effect is in harmony with the results of Buck et al. *(5)* on frozen peaches. Doubling the quantity of pectin had no further beneficial effect.

Another point of interest was that the control of browning was considerably easier in some varieties of apples than in others. It seems, also, that for a given variety, the ease or difficulty of control varied somewhat in different seasons, and possibly with location of production. To be certain that a method of browning control will work under all conditions, it should be tried in several widely distributed apple-growing areas and several seasons, before recommending it for general use. Usually, the browning of apples of the McIntosh variety was the easiest to control and that of Northern Spy the most difficult. It was possible to get satisfactory control of browning with lower concentrations of sulfur dioxide in McIntosh apples than with the other varieties tested.

While the present results do not pretend to solve the problem, it is hoped that they show the direction of further study for eventual practical applicability.

SUMMARY

A study of dipping solutions for the pretreatment of apple slices to be preserved by freezing and storage at 0° F. (—18° C.) revealed that pectin tends to reduce browning in the thawed slices. A combination of ascorbic acid, pectin, and sulfur dioxide seems to possess particular merit.

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The Effect of the Length of Soak on the Quality of Canned and Frozen Montmorency Cherries[a, b]

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Data are presented to show effect of soaking on raw fruit losses and on quality of canned and frozen red cherries as determined by tenderness, color and soluble solids.

It is the common practice in the handling of Montmorency cherries for processing to store them in soaking tanks for approximately 6 to 24 hours before pitting and processing. Although little or no actual data have been obtained on the effect of this soaking treatment, it has been generally assumed that the cherries become firmer, increase in volume and weight, and that less damage occurs during pitting due to tearing and loss of juice. In 1948 some preliminary data obtained did not appear to substantiate this opinion and so in 1949 more extensive experiments were conducted to determine the effect of various soaking periods on the pitting characteristics, juice loss, and percentage of culls in the fresh fruit and on the quality of the canned and frozen cherries.

EXPERIMENTAL METHODS

Montmorency cherries grown and harvested commercially in the Benton Harbor, Grand Traverse and Hart-Oceana areas of Michigan were used for this study. Fruit in two stages of maturity were used, namely immature and mature, as determined by color and other characteristics.

The cherries were transported by truck to the Michigan State College food processing laboratory and on arrival their temperatures were recorded and the cherries were weighed. Representative lots were removed for hydrocooling and air cooling and the remainder were put in a 200-gallon soaking tank continually supplied with fresh tap water of an average temperature of 57° F. (14° C.) at a rate of approximately 25 gallons per minute. Representative 25-pound lots were removed from the soaking tank after 0, 3, 6, 12, 18, 24, 36, 48 and 72 hours. These lots were drained, weighed and sorted to remove damaged fruit. The sound fruit was pitted in a Dunkley cherry pitter of pilot plant capacity and the resulting loss in weight due to pits and juice was recorded.

The cherries removed for hydrocooling were cooled to an internal fruit temperature of 40° F. (4.5° C.) and 57° F. (14° C.) in iced water at 32°-33° F. (0° C.). The time required for the fruit to cool to these temperatures varied from 15 to 30 minutes, depending upon the initial fruit temperatures. The air-cooled cherries were cooled to an internal fruit temperature of 40° F. (4.5° C.) in still air at 32° F. (0° C.), requiring 12 to 18 hours storage. These lots, after cooling, were sorted and pitted as described for the soaked cherries.

The pitted cherries were canned in No. 2 cherry enamel cans. Sixteen ounces of pitted cherries were filled in each can, covered with hot water, exhausted, processed in boiling water for 12 minutes, cooled and stored at 50° F. (10° C.). For freezing, the pitted cherries were packed with sugar (5 parts cherries plus one part sugar) in one-pound plastic bags in cartons frozen at −10° F. (−23° C.), and stored at 0° F. (−18° C.).

After 4 to 6 months' storage, the drained weight, soluble solids, tenderometer readings, color and grade of the canned and frozen cherries were determined. The canned and frozen cherries were removed from storage and allowed to reach room temperature 70° F. (21° C.). The canned cherries required approximately 2 hours, and the frozen cherries approximately 7 hours to reach this temperature.

Drained weights and grades were determined according to the U. S. Standards for "Grades for Canned and Frozen Red (Sour) Pitted Cherries" *(1, 2)*. The percentage of soluble solids was determined with an Abbe refractometer. Tenderometer determinations were obtained with the Tenderometer using 100 g. samples of the canned cherries and 25 g. samples of the frozen cherries. The readings were made on Scale 1.

Color was measured using a Coleman spectrophotometer Model 14 set at 520 mμ. Initial data indicated that a measure of the red pigment in a water extract is provided by the transmittance in the absorption band centered at this point. It was also found that in both the canned and frozen cherries the color was evenly distributed throughout the fruit and drained juice and therefore color determinations were made only on the juice. The drained juice was clarified by mixing with Hyflo Supercel and filtering by suction through Whatman No. 1 filter paper. It was then diluted with five-fold volume of distilled water and the percent transmittance determined.

RESULTS

The results on the percentage of cull fruit, pit loss and loss of juice in pitting are given in Table 1. The loss of fruit due to cullage increased with increased time of soaking. In the immature fruit 6 hours' soaking increased the culls two and a half fold. There was no increase in cull fruit in the hydrocooled lots, but the amount of cull fruit in the air-cooled lot was nearly doubled. In the mature fruit the amount of cull fruit,

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TABLE 1

Effect of Soaking Treatment on Percentage of Cull Fruit, Pit Loss and Juice Loss on Montmorency Cherries

Treatment	Immature Fruit				Mature Fruit			
	Cull Fruit,	Pit Loss,	Juice Loss,	Total Loss,	Cull Fruit,	Pit Loss,	Juice Loss,	Total Loss,
	%	%	%	%	%	%	%	%
No soaking	7.1	9.9	16.8	33.8	4.8	9.7	5.9	20.4
3 Hours of soaking	....	....	....	....	6.3	9.7	7.3	23.3
6 " " " "	18.3	12.5	15.9	46.7	9.2	9.9	7.3	26.4
12 " " " "	20.3	11.4	8.7	40.4	21.5	10.0	8.0	39.5
18 " " " "	....	....	....	....	25.2	8.9	7.7	41.8
24 " " " "	18.8	11.0	8.6	38.4	18.1	10.0	6.9	35.1
36 " " " "	30.6	10.7	7.2	48.5	25.8	10.2	7.1	43.1
48 " " " "	42.1	10.7	7.5	60.3	24.6	9.8	7.2	41.6
72 " " " "	....	....	....	....	38.0	11.4	7.0	56.4
Hydrocooled to 40° F.	7.8	9.8	9.3	26.9	7.0	9.4	9.7	26.1
Hydrocooled to 57° F.	6.2	11.4	8.5	26.1	5.9	9.7	8.2	23.8
Air cooled to 40° F.	13.2	10.4	7.0	30.3	18.3	10.1	5.2	33.6

although it gradually increased during the inital period of soaking, did not become excessive until after 12 hours of soaking. Since the temperature of the soaking bath used in this study was about 5°-12° F. (3°-7° C.) higher than is maintained in most Michigan commercial plants, this may, in part, account for the high cullage losses obtained. The effect of soaking temperatures on amount of cull fruit obtained during soaking is being further investigated.

The weight loss due to pits was relatively constant in all treatments. The ease with which the cherries pitted without tearing indicated that for satisfactory pitting a soaking period of at least 6 hours was necessary. The hydrocooled and air-cooled cherries pitted as well as the cherries soaked for 6 hours or longer. These results seem to indicate that for pitting with minimum damage to the fruit it is important that the cherries be cooled and that soaking, as such, has no beneficial effect except that it provides a convenient means for cooling and storing large volumes of fruit at a minimum of expense.

The juice loss due to bleeding after pitting in the immature cherries was about twice as great in the fruit soaked for less than 12 hours than in the fruit soaked for 12 hours or longer. The juice loss in hydrocooled and air-cooled cherries was similar to that found for the cherries soaked 12 hours or longer. In the mature cherries, there was a slight tendency towards less juice loss the longer the soaking time.

The overall loss due to cull fruit, pit loss and juice loss showed a gradual increase with longer soaking periods. The data tends to indicate that the loss of fruit from discoloration and bruise damage is of greater importance than the loss in weight due to pitting and bleeding.

CANNED AND FROZEN CHERRIES

There was no correlation between drained weights and the time of soaking. All lots of canned immature cherries were below the recommended minimum drained weight requirements, while all the mature cherries met such requirements. The drained weights on the frozen cherries showed the same trend as the canned cherries. All immature lots had a lower drained weight than the mature cherries.

The results for percentage of soluble solids, color and tenderometer readings on the canned cherries are given in Table 2. In the canned cherries the loss of soluble solids increased as the length of soaking time increased. Cherries cooled either by hydrocooling or in cold air showed little or no loss of soluble solids. The loss of soluble solids was accompanied by decreasing tartness and flavor in the processed product as well as in the fruit prior to canning. From the data obtained, it appears that a soaking treatment of 12 hours, at a temperature of 57° F. (14° C.), is the maximum that can

TABLE 2

Effect of Soaking Treatment on Soluble Solids Content, Color and Tenderometer Readings of Canned Montmorency Cherries

Treatment	Immature Fruit			Mature Fruit		
	Soluble Solids, %	Color (Transmittance), %	Tenderometer readings	Soluble Solids, %	Color (Transmittance), %	Tenderometer readings
No soaking	10.8	49.4	16.9	12.9	39.5	....
6 Hours of soaking	10.0	48.9	18.7	12.8	....	15.0
12 " " "	9.5	51.0	20.8	11.9	43.7	16.7
18 " " "	....	....	....	11.7	42.1	17.0
24 " " "	9.3	54.5	27.0	11.5	45.8	23.9
36 " " "	9.0	56.1	35.1	11.1	46.0	22.6
48 " " "	8.9	57.1	33.4	10.9	48.0	27.0
72 " " "	....	....	....	10.2	48.6	29.5
Hydrocooled to 40° F.	11.0	49.4	14.4	12.9	41.5	16.7
Hydrocooled to 57° F.	10.9	50.2	16.0	13.1	37.0	16.5
Air-cooled to 40° F.	10.9	49.1	18.0	13.1	37.5	20.0

be used without resulting in deterioration of quality due to the loss of soluble solids. The data obtained on the frozen cherries showed no correlation between soluble solids content and length of soaking. However, the frozen cherries did show increasing lack of tartness the longer the soaking period.

The red color of the canned and frozen cherries decreased as the length of the soaking period was increased. In the frozen cherries the loss of red color was not as great as in the canned cherries, but there was a marked increase in the amount of brown discoloration around the stem end and the cut surfaces in the cherries which were soaked for longer periods.

The tenderometer readings on the canned and frozen cherries increased as the length of the soaking period increased. This was not as marked in the frozen cherries as in the canned cherries. The resistance of the thawed frozen cherries to the shearing action in the tenderometer was such that 25 grams gave tenderometer readings equal to those obtained for 100 grams of canned cherries.

SUMMARY

The effect of the length of soak on the quality of canned and frozen Montmorency cherries was studied during 1949. The data obtained indicated that soaking cherries for more than 12 hours in running tap water at 57° F. (14° C.) results in considerable loss of fruit due to cullage, loss of soluble solids, color, and increased toughness as measured by the Tenderometer.

The results also showed that soaking, as such, is not essential for preventing excessive losses due to pitting damage and loss of juice since cherries which were either hydrocooled or air-cooled pitted as well as cherries soaked for 6 hours or more. Thus one of the principle objectives of the soaking treatment appears to be that of temperature reduction in the raw product. Soaking does provide a convenient means of cooling and storing large volumes of fresh fruit.

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The Use of Packing House By-Products for Animal Feeds[a]

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A REVIEW

The various packing house by-products used as animal feed (especially for swine and chicks) are discussed together with the role of high-protein concentrates, the "animal protein factor" and the economic aspects of animal feeding.

In the early days of the meat packing industry, lard, tallows, and greases were rendered by what is still known as the wet process. Fatty tissues were put into a conical-bottomed tank and steam turned in under pressure. The fat was cooked out and rose to the surface from where it was drawn or skimmed off. The protein residue, both solid and in solution, was removed from the tank, dried, and sold. This residue had a high nitrogen content and, prior to 1900, was used as fertilizer.

A great change came about in pig feeding practice when Professor Plumb of Purdue University in 1901 fed some of this protein concentrate, called tankage, to pigs along with corn. It had been standard practice before that time to fatten hogs on corn alone because, except for the few farms that had an ample supply of milk, little or no high protein feed was available.

Professor Plumb found when he fed this high protein concentrate and corn that his pigs grew faster than they ever had on corn alone. He could get the pigs to market weight in seven months or less, and use considerably less corn in doing so. Before that time, few pigs had reached market weight in less than nine months, and most had taken considerably longer. By getting the pig off to market sooner and using less feed per animal it was now possible to raise two litters of pigs a year instead of one. This increased efficiency of pork production meant more profit to the farmer and soon the pigs' reputation as a "mortgage lifter" was made.

A few years later, another protein concentrate came on the market when a new process for rendering fats came into use. With the advent of the dry-melter, a protein residue known as "meat scrap" was produced which differed from tankage in that it was a dry-rendered product. In this dry-rendering process the fatty tissues are put into a tank that is heated by steam pressure in the shell. The fat is cooked out and the water evaporated off at the same time.

According to these official definitions, tankage, which may be digester tankage, meat meal tankage, or feeding tankage, is the finely ground residue from animal tissues exclusive of hair, hoof, horn, manure and stomach contents, except in such traces as might occur unavoidably in good factory practice, especially prepared for feeding purposes by tanking under live steam, or by dry-rendering or a mixture of the products. Meat scrap, or meat meal, is the finely ground, dry-rendered residue from animal tissue exclusive of hair, hoof, horn, blood, manure and stomach contents, except in such traces as might occur unavoidably in good factory practice. When these products contain more than 4.4 percent of phosphorus, which is a measure of the bone content, the word "bone" must appear in the name, as "tankage with bone," or "meat and bone scrap."

Nowadays, most tankage is sold as 60 percent protein digester tankage and meat scrap is generally sold as meat and bone scrap. Bone is put into the meat scrap because it supplies needed calcium, phosphorus, and other minerals, and because the scraping action of bones in the dry-melter help to keep the inner shell clean.

The chief differences between meat scrap and tankage are that meat scrap, or meat and bone scrap, must be dry-rendered and must not contain blood, whereas tankage may contain blood and may be either dry rendered, wet-rendered, or a mixture of the two.

According to the Bureau of Agricultural Economics, United States Department of Agriculture, there was a

[a] Presented at the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 24, 1950.

total production in 1949 of over 774,044 tons of meat scrap and tankage. Approximately 77 percent of this was dry-rendered meat scrap and 23 percent was tankage. Dry-rendering, with consequent production of meat scrap, has to a large extent superseded the older wet-rendering process because it is a more efficient operation.

During the fifty years that feeding tankage has been produced, it has been used chiefly in hog feeding, while meat scrap, or meat and bone scrap, has been used in poultry feeding. One of the reasons that tankage has been used so extensively in hog feeding is because of its amino acid composition and consequent supplementary power when combined with corn. In the corn belt the cheapest and most abundant source of energy for hog rations is corn, but the protein of corn is seriously deficient in two amino acids, lysine and tryptophan. Tankage contains a good supply of both lysine and tryptophan which help balance out the deficiencies of the corn protein. Tankage also contains minerals that are needed for growth, and which are deficent in cereal grains. The calcium and phosphorus of the bone, which is present in tankage, is readily utilized by the growing pig. In poultry feeding the phosphorus of bone is more readily available than is the phytin phosphorus of the cereals.

Swine rations have tended, for the most part, to be relatively simple; they contained fewer ingredients than most poultry rations and it is here, in combination with corn, that tankage has found its greatest usefulness. You will remember that tankage is permitted to contain blood while meat scrap is not. Many of the tissues that go into these products do not have a high tryptophan content; fatty tissue residues, for instance, are rather low in tryptophan. The protein in blood, however, has a high content of tryptophan so that tankage containing blood will supply the tryptophan necessary to make up that deficiency in corn.

This supplementing power of tankage containing blood is not a one-way street, however. The protein of blood is one of the rare exceptions of an isoleucine deficiency, but that is balanced out by the isoleucine that is present in the other tissues that go into tankage combined with what is in the corn of the ration.

Meat scrap, or meat and bone scrap, has been used chiefly in poultry feeding because it does not contain blood, and poultry men have always felt that it was more readily consumed by poultry than was tankage. The shortage of tryptophan was of little consequence because poultry rations tended to be more complicated than pig rations and contained other ingredients that had a good supply of tryptophan.

In the feeding of farm animals, as in human food, protein is a high-priced nutrient. In order to get the greatest feed value per dollar, the feeder has to combine the available ingredients in such a way as to get the greatest good out of them. Since corn is perhaps the best source of energy in feeds and since corn contains a certain amount of protein which is not complete in its amino acid pattern, the most efficient protein supplements will be those that supplement the protein of corn. There is no need to supplement corn with a protein concentrate that is complete in itself and has all the amino acids the animal can utilize for tissue building. If we did, the protein of corn would be wasted. It is true, that if the protein is not used as a source of amino acids, it can be used by the body as a source of energy, but protein is too costly a material to use for that purpose. From a standpoint of efficiency in amino acid utilization, the best protein supplements to use should be the ones that supplement the proteins of the cereal portion of the ration.

Any one protein does not need to have a complete amino acid pattern to make a good protein supplement. The biological value of a protein means nothing to a practical feeder, because in general farm practice a single protein is never fed. There are always mixtures of proteins in practical feeds, so what the feeder wants to know is, "How will this protein perform when mixed with the other ingredients that are available"?

Mitchell and Kick pointed out over 20 years ago that both corn and tankage protein had comparatively low biological values when fed separately, but when they were mixed and fed to pigs the biological value of the mixture was higher than for either alone. This indicates that there is a definite supplementing effect. Because of these supplementary effects, and because cereals always will be used, it is useless from a practical feeder's point of view to try to determine the actual feeding value of a single protein source. The common practice of laboratories in feeding a so-called purified ration containing a single protein gives information of value only for that particular type of purified ration, and the feeder is still left in the dark concerning its value in practical feeding operations. For information here, he must turn to the large number of feeding tests that have been conducted at many agricultural experiment stations, and to his own experience in feeding packing plant by-products.

For a number of years it was common practice to feed corn and tankage; later it was found that a mixture of proteins gave even better results. Now, it is generally known that mixtures of corn, tankage, one or more plant protein concentrates, alfalfa meal, and sometimes supplementary minerals and vitamins, give better results than the simpler type of rations.

Some meat and bone scrap has been fed to pigs instead of tankage. In most cases, the feed mixer has assumed that the meat and bone scrap had value equal to the tankage. A number of feeding tests were run several years ago at some of the experiment stations which showed that meat scrap had a high value in swine rations and several reports indicated that they could be used interchangeably. This is true in some instances, but not in all cases.

There is a variation, from one packing plant to another, in the ingredients going into tankage and meat scrap. Each plant has its own production schedule and system, which sends tissues to the wet-rendering tanks in one plant that might go to the dry-melters in another. Then, too, as mentioned earlier, tankage contains a certain amount of blood while this ingredient is excluded from meat scrap. Since a meat and bone scrap containing 50 percent protein must have a larger percentage of bone than a 60 percent protein tankage, there is a difference in mineral content and also a consequent difference in the source of protein because bone itself contributes a considerable amount of protein. Some of the early tests comparing tankage with meat scrap were run with materials that we now would call meat meal. Meat meal is a high protein product that is often made from tissue of low fat content, such as organs and glands. These products were not put into regular meat scrap because they had a low fat content, but rather were dried separately and sold as a separate product. Meat scrap, or meat and bone scrap, gives

excellent growth on laboratory animals when mixed into a typical swine type ration, if it contains a sufficiently high level of tryptophan. If it contains a low level of tryptophan, the addition of 2 to 4 percent of dried blood to the ration supplies the needed amount of tryptophan. There was a time when the dried blood was thought to be of no value in the feed. Now we find that it gives approximately the same growth response as the addition of 0.2 percent of DL-tryptophan. If the ration contains a mixture of proteins, some of which supply enough tryptophan, the animal's requirements will be met and another tryptophan carrier is not needed.

Meat scrap, or meat and bone scrap, has usually been used in poultry feeding because over the years it has been an economical source of several nutrients that poultry require for rapid growth, for high hatchability of eggs, and for viability of the chicks so hatched.

Poultry rations have generally tended to be more complex than swine rations, containing a greater assortment of ingredients. The tryptophan problem has not worried the poultry feeder because his rations contained such things as wheat bran, wheat middlings, alfala meal, and soybean oil meal, each of which has a moderately high level of tryptophan in its protein. Poultrymen liked to use meat and bone scrap because it supplied other amino acids, fat, minerals from its bone content, and certain other factors that seemed to make chicks grow faster, as well as to increase the hatchability of eggs from the laying flock.

During the war years, many attempts were made to formulate a good poultry ration without the use of some protein from an animal or marine source, but in every case it was found that it was advantageous to include some of these proteins. There gradually came into being the concept of an "animal protein factor," some mysterious substance in these animal source proteins that stimulated growth in chicks and increased hatchability of eggs.

It was at one time thought that animal source proteins were superior to plant source proteins because, being from an animal or marine source, they were made up of the right assortment of amino acids to give optimum results. When it became possible to make a fairly accurate determination of amino acids in proteins, it was discovered that it took more than a complete protein or an optimum amino acid mixture to produce results. There were suppositions that these animal proteins contained "growth factors" or "protein utilization factors," probably vitamin in nature, that might account for their action.

Eventually, vitamin B_{12} was discovered, and when methods became available for measuring it we found that these animal source proteins contained the new vitamin. This, then, was part of the reason that animal source proteins had given better results than the vegetable proteins; but it wasn't the only reason. It soon became clear that an excess of vitamin B_{12} did not produce the results that could be secured from good animal source proteins. While vitamin B_{12} is necessary for good growth of chicks and hatchability in eggs, it still is not the whole story and a further increase in growth stimulation can often be obtained from feeding proteins that contain the animal protein factor.

We don't know just yet what the status of the so-called "animal protein factor" will be in the light of more recent advances regarding the feeding of certain antibiotics, such as aureomycin.

It is sometimes said that tankage and meat scrap are not as good now as they used to be, and that the quality is deteriorating because so much organ and glandular material is now diverted into dog food. It is true that a large amount of organ and glandular products is going into dog food, but the percentage that was diverted from meat scrap or tankage production is very small. Such materials as now go into dog food seldom, if ever, found their way into the regular meat scrap and tankage production. Many of these materials were at one time used as "liver and lung meal," "liver and glandular meal," or high protein meat meal. Since these products contained less fat in the beginning than the finished meat scrap or tankage, it would have been a sheer waste to tank them along with other items to be rendered because they would absorb fat, thus reducing the fat yield from the tank. They were usually cooked and dried separately. Condemned organs and glands are still cooked and dried, and most of them find their way into meat scrap or tankage, as they have for many years. It is possible that the percentage of condemnations is smaller now than in past years due to better disease control on the farms and ranches.

Processing of the products should be better now than it used to be, because of the more exact control of cooking temperatures and times. Dry rendering is generally considered preferable to wet rendering because the fats are cooked out and the water evaporated off in one operation where there is plenty of agitation in the melter to prevent local overheating. Dry rendering is gradually replacing wet rendering.

Every new discovery in the field of nutrition has a bearing on the future demand for protein concentrates of animal origin. When vitamin B_{12} was first isolated and then made available in the form of concentrates, it was tried in all types of feeds. While it was a big help in a poor ration it did not do so much good in a good ration. It has been observed that antibiotics stimulate growth and increase feed efficiency. Here again, it appears that the growth stimulation is greater on a poor ration than it is on a good one. Our results to date indicate that these new concentrates containing vitamins and/or other factors will act as protein extenders, but will not yet replace all of the nutritive factors that are peculiar to protein concentrates of animal or marine origin.

The feed manufacturer must produce a feed that will give good results whenever it is fed. He can not afford to increase the cost of his ingredients unduly, nor to cheapen them by using poor ingredients. Packing house by-products will continue to be used as long as they produce satisfactory results economically. The same can be said for any other ingredient, old or new. The new supplements that are said to influence growth in some cases will be used only if it can be done economically, considering the cost and the results achieved.

If animal source proteins are removed from the feeds, they must be replaced with substitutes that will supply the nutrients contained in the animal proteins: amino acids, vitamin factors, minerals, and possibly fat. When the cost of the substitutes is calculated and balanced against results achieved, it is my opinion that packing house by-product animal feeds will continue to be used.

Observation of Color Changes in Some Processed and Stored Foods[a]

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Objective measurements of physical properties related to the color of various foods have been made with a recording spectrophotometer and a photoelectric reflectometer. The general nature of the changes in these properties during various processing and storage procedures has been detected with either type of instrument. For the purposes of product appraisal or process evaluation, these observed changes and differences have been evaluated in terms of their relative visibility to the observer. The experimental procedures for measuring the color of fresh, pod-stored, and frozen peas, frozen corn, and dehydrated carrots are described and the observed color changes due to differences in processing, packaging, or storage are presented and discussed.

Color is one of the most evident characteristics of food products and is recognized as an important quality factor. The consumer associates certain color characteristics with fresh and wholesome quality. Thus the extent to which original natural color is preserved during processing and in subsequent storage is one important criterion of processing procedures.

The objective indication of color differences in foods has usually been attempted in a simplified, indirect way that involves measurement of properties of extracted critical color fractions. The use of an extracted color method is not a direct measure of visual color and its use to indicate possible color changes in the original product depends upon a close relationship between the extracted portion and the color characteristics of the original product. Some fractions influencing color may be difficult to remove or may not be removed by the extraction method used. Total color differences, measured more directly in terms of what an observer sees, depend upon differences in the reflectance characteristics of the samples and can be studied by means of reflectance spectrophotometry and colorimetry.

However, the visual color of an object is not an unchangeable characteristic of the object itself, dependent only upon its reflectance properties, but is also dependent upon the quality of the illuminating light and the sensitivity of the observer's eye. The measurement and description of color are thus "psychophysical" problems. In recent years a method has been devised that makes possible objective psychophysical description of the color of an object illuminated by a standard illuminant and viewed by a "standard observer" *(1)*. The color is described as being equivalent to the stimulus produced by a mixture of certain standard colors. Results are usually expressed in one of two systems: (a) the tristimulus system in which the equivalent stimulus is a mixture of the three standard I. C. I. (International Commission on Illumination) primaries, or (b) the white light-colored light system in which the equivalent stimulus is a mixture of light from a standard heterogeneous illuminant and a pure spectrum color. In the application to food work the necessary experimental data have been obtained with spectrophotometers or photoelectric tristimulus colorimeters.

Spectrophotometric Method. Reflectance spectrophotometric curves (which indicate the ability of samples to reflect light of various wavelengths) were obtained with a recording spectrophotometer *(4, 11)*. The tristimulus values (X, Y, and Z), expressed as results which would be obtained by the I. C. I. observer rating samples under I. C. I. standard illuminant C, were obtained by integration of these curves by standard methods *(5)*. The trichromatic coefficients (x and y) were calculated and dominant wavelength and excitation purity read from large scale chromaticity charts *(5)*.

Photoelectric-colorimetric Method. A photoelectric reflectometer *(6)* has also been used to study reflectance properties of foods. With this instrument three separate readings are made with amber, blue, and green filters, designated A, B, and G, respectively. An approximate I. C. I. trichromatic specification of the sample color may be calculated *(7)*. However, although the chosen source-photocell-filter sets are nearly equivalent to the spectral response of the I. C. I. observer, differences are to be expected between values of luminous reflectance, dominant wavelength, and purity calculated from reflectometer and spectrophotometer results. In comparing results from the two instruments, differences in illumination and viewing geometry must be remembered. Thus the reflectometer reading G gives a measure of "directional" luminous reflectance for illumination at 45° and viewing at 0°.

Another colorimetric index obtainable with the reflectometer has been useful in food work. This index, defined by (A-B)/G, is called "yellowness" *(7)* and gives values increasing from zero for the magnesium oxide used as standard or other nonselective surface to positive values for yellowish or reddish surfaces and negative values for bluish surfaces.

Conversion to Other Descriptive Systems. The visual detectability of food color differences is not directly apparent from results expressed in I. C. I. notation, since equal distances in the I. C. I. chromaticity diagram do not mean equal visual differences. The significance of the measured color differences is clarified by transformation to a "uniform-chromaticness-scale" diagram in which distances more nearly represent the visual perceptibility of the color differences. In this work, color differences, ΔE, were calculated as described by Hunter *(7)* and are expressed in "NBS (National Bureau of Standards) Units of Color Difference." This unit is intended to be of such size that measured differences of less than one unit would represent perceptually unimportant color differences.

It is difficult, if not impossible, to visualize the color specified by tristimulus values, by values of luminous reflectance and chromaticity (Y, x, y), or even by values of dominant wavelength and purity. In some instances the picture can be simplified by conversion, by tables and charts available *(12)*, to the

[a] Presented in part before the Ninth Annual Meeting of the I. F. T., San Francisco, California, July 12, 1949.

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Munsell Notation. This system evaluates the three psychological color attributes, namely, hue, lightness (Munsell value), saturation (Munsell chroma)—on scales of approximately equal visual steps and provides a set of color plaques which help in the actual visualization of color data.

The present paper describes some of the procedures used and results obtained in applying the above methods to the observation and description of color differences and changes in some foor products. A more detailed description of these methods as applied in food research has been given elsewhere *(2)*. Where possible, measurements have been made with both available instruments in order to determine the capabilities of each when applied to food problems. Various sampling and preparation techniques have also been tried so that most suitable handling can be given to similar samples at future times.

PEAS. COMPARISON OF THE COLOR OF FROZEN AND DEHYDROFROZEN PEAS WITH FRESH AND STORED POD PEAS

Experimental Procedure. The color of frozen, dehydrofrozen *(14)* and fresh and stored pod peas was measured with the recording spectrophotometer and the reflectometer. The peas (Laxton Progress variety) for freezing and storage in the pod at 33° F. (1° C.) were picked and transported to the laboratory in ice. The freezing and dehydrofreezing were done as rapidly as possible after arrival. The peas for 75° F. (24° C.) storage were not iced at any time. Three different lots of peas have been tested in two different seasons.

Samples of the pod-storage peas were taken at intervals up to 7 days for the 75° F. storage and up to 28 days for the 33° F. storage. Precautions in shelling, cleaning, sizing, mixing, and sampling were taken that were considered adequate for the purposes of the various tests. Samples for color determination were cooked in distilled water adjusted to pH 8.0 with sodium bicarbonate. For measurement in the spectrophotometer, samples were packed whole in 2 cm.-thick flat glass cells, and the cells then filled with water to reduce specular reflection from the curved surfaces of the peas. For measurement in the reflectometer the whole peas were packed flat in a glass tray 2-cm. deep. The reflectometer was so mounted that the sample tray was viewed in a horizontal position.

The character of the spectrophotometric differences observed is indicated in Figure 1 which shows average curves for the three lots of peas at representative storage periods. The results are indicated in a numerical way in Table 1, which gives average data for the three lots

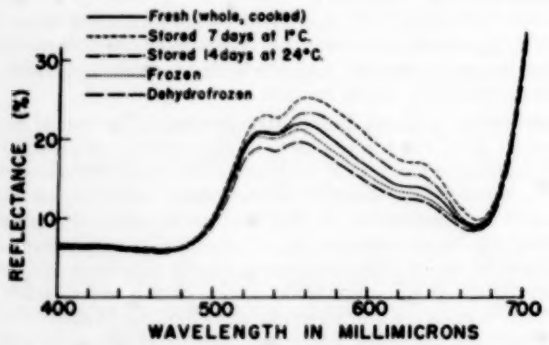

FIG. 1. Typical reflectance spectrophotometric curves for fresh, stored, frozen and dehydrofrozen peas (whole, cooked).

of peas as measured on the recording spectrophotometer and on the reflectometer.

In general, the peas held in the pod result in a lighter and yellower cooked product than the fresh peas. The color of both the frozen and dehydrofrozen product is darker than the fresh product. The differences in lightness are apparent in the vertical shifts of the spectrophotometric curves and are indicated numerically by the values of luminous reflectance (Y) and directional luminous reflectance (G). The yellowing is seen in the increase in dominant wavelength (λ) and in the yellowness (Yns). Under the conditions of the experiment, the color changes during the first 2 or 3 days are not easily distinguished at the two temperatures of storage. After 7 days the 75° F. sample had changed considerably more than the 33° F. samples (see ΔE). The latter continued to change slowly throughout the storage period.

TABLE 1

Comparison of Color of Frozen and Dehydrofrozen Peas with Fresh and Stored Pod Peas as Measured on the Recording Spectrophotometer and the Reflectometer

Peas	Days' storage	Spectrophotometer					Reflectometer	
		Y, %	λ	p	ΔE	G	Yns	ΔE
Fresh (pod peas, stored at 33° F.)	0	17.9	567.3	45.1	....	0.132	0.568	....
	1	17.8	567.0	44.9	2.5	0.134	0.572	1.8
	3	18.8	568.9	45.1	3.7	0.136	0.595	4.0
	7	19.0	568.7	46.3	4.2	0.136	0.598	4.0
	14	19.3	568.7	48.5	5.4	0.143	0.630	8.0
Fresh (pod peas, stored at 75° F.)	1	18.5	567.2	44.7	3.5	0.138	0.585	1.7
	2	18.7	567.0	48.5	3.5	0.134	0.574	2.0
	3	19.4	567.8	48.4	3.8	0.133	0.588	2.8
	7	21.0	569.1	52.3	8.0	0.161	0.626	7.7
Frozen	....	17.6	566.0	44.6	3.0	0.130	0.544	1.6
Dehydrofrozen	....	16.7	567.0	45.0	3.7	0.120	0.550	2.9
Standard deviation [c]	....	0.4	0.4	0.8	....	0.004	0.010	....

[c] Standard deviations are reported here to give an indication of the reproducibility of the determination of the various color indices. These results are derived from measurements on 18 separate subsamples of whole peas, each separately cooked and otherwise handled as described.

Comparison of Visual and Instrumental Results. For the third series of peas, desirability of color was evaluated by judges subjectively on samples from the same cooking lot of peas. Judges indicated that they considered the color of the sample very attractive, attractive, indifferent, unattractive, or very unattractive. These designations were converted to scores of 5 to 1 respectively and the average scores were compared with objective results. The observed correlation coefficient for directional luminous reflectance (G, in percent) versus judges' score was $r = -0.80$ (slope $= -0.83$ = decrease in judges' score for 1% increase in reflectance, standard error of estimate $= 0.65$). The correlation coefficient for yellowness versus judges' score was $r = -0.94$ (slope $= -2.61$ = decrease in judges' score for unit increase in yellowness, standard error of estimate $= 0.38$). Thus the lighter and yellower peas were judged to be less desirable in color.

COLOR CHANGES IN FROZEN PEAS STORED AT −10°, 0°, AND +10° F.

Experimental Procedure. Measurements have also been made of color changes that occur in frozen peas during storage at different temperatures. Five different lots of peas (Laxton's Progress type) were carefully picked, sized and processed *(9)*. Samples of each lot were stored at three different temperatures, −10°, 0°, and +10° F. (−23°, −18°, and −12° C.). Measure-

ments were made at intervals of 8 weeks for a period of one year. Samples for color measurement were cooked and otherwise treated as described above except that measurements were also made on blended samples. These samples were blended with an equal weight of distilled water and viewed in a 1 cm.-thick flat glass cell in the spectrophotometer and a 1 cm.-deep aluminum tray with cover glass in the reflectometer.

The numerical color differences observed in this series of peas were relatively small, in terms of visual perceptibility, even after storage for one year. Furthermore, the color differences observed varied somewhat in nature and extent in the different lots of peas. Changes in lightness appear to be more variable in the different lots and therefore less significant than changes in chromaticity. General trends of color change were similar in each lot and to indicate these trends, the values from all five lots of peas are combined and reported as one single large set of data.

As might be expected, the samples stored at —10° F. changed the least with storage time. The effect of storage temperature on the reflectance characteristics of the peas is illustrated in Figure 2, which shows characteristic results in two of the lots for samples stored at —10° F. and +10° F. It will be noticed that there is a difference in lightness in Lot A but probably very little visual difference in lightness in Lot B. However, in both lots the reflectance for the peas stored at higher temperatures is greater in the regions of 490 mμ and 580 mμ relative to the reflectance in the region of 540 mμ. Use has been made of the latter observation to define an index, which might be called "greenness" (gns), to help describe differences observed in the peas. Thus

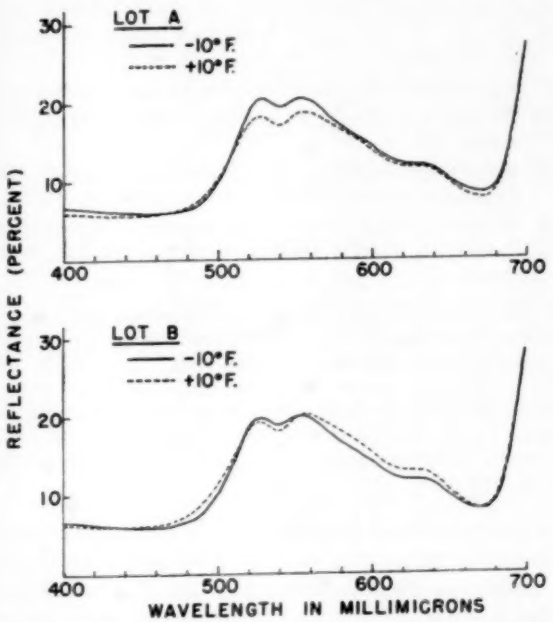

FIG. 2. Effect of storage temperature on the reflectance properties of two different lots of frozen peas. (Samples stored for 40 weeks).

$$gns = R_{540}/R_{490} + R_{580}$$

where R_{540}, R_{490}, R_{580} are reflectances read from the recorded spectrophotometric curve at 540, 490, and 580 mμ respectively. A similar index can be calculated from reflectometer readings as

$$gns = G/A + B$$

where G, A, and B are readings with the green, amber, and blue filters respectively. Observed changes in greenness calculated according to these definitions are given in Table 2. The "greenness" decreases in the 0° sample but more significantly so in the +10° samples. The reflectometer is not as sensitive as the spectrophotometer in the measurement of this index because of the broad band nature of the three filters.

TABLE 2

Changes in "Greenness" of Peas Stored at —10°, 0°, +10° F. as Compared with Peas Which Were Not Stored

Sample and form	Weeks' storage	Spectrophotometer			Reflectometer		
		—10°	0°	+10°	—10°	0°	+10°
Cooked, whole	8	0.015	0.018	—0.011	0.003	0.003	0.001
	16	—0.021	—0.020	—0.060	—0.002	0.001	—0.012
	24	0.012	—0.020	—0.052	—0.004	—0.016	—0.022
	32	0.009	—0.005	—0.068	0.002	—0.007	—0.023
	40	0.013	—0.025	—0.077	0.000	—0.019	—0.027
	55	0.014	—0.045	—0.087	0.007	—0.014	—0.042
Cooked, blended	8	0.021	0.013	—0.005	0.009	0.011	0.005
	16	0.003	—0.009	—0.028	—0.002	0.003	—0.009
	24	0.018	—0.011	—0.035	0.004	—0.004	—0.016
	32	0.010	—0.015	—0.050	0.005	—0.001	—0.020
	40	0.005	—0.030	—0.077	0.001	—0.011	—0.026
	55	0.018	—0.016	—0.078	0.006	0.004	—0.028

The numerical changes observed in the three psychophysical indices, Y, λ, and p, as calculated from the recorded spectrophotometric curves are variable to the extent that probably only general trends of change can be indicated. The average results for the five lots given in Table 3 are presented as differences between samples stored at 0° and +10° F. and samples stored at —10° F. It is seen that peas stored at the higher temperatures become darker (Y decreases), yellower (λ increases), and grayer (p decreases). Actually, in terms of visual perceptibility, the observed changes are relatively small, even those observed for peas stored for one year. The visual perceptibility of the changes is more easily seen in the results shown in Table 4. These results were calculated from readings made with the reflectometer and averaged for the five lots of peas. The greater rate of change of visual color in the samples stored at +10° F. is apparent from the relatively larger values of Δ E after about 24 weeks. It is interesting to note that while an apparent general decrease is observed in the value of the luminous reflectance (Y, Table 3) as

TABLE 3

Average Differences in Luminous Reflectance (Y), Dominant Wavelength (λ), and Purity (p) between Frozen Peas Stored at 0° F. and +10° F. as Compared with Peas Stored at —10° F.

Sample and form	Weeks' storage	(0° F.) — (—10° F.)			(+10° F.) — (—10° F.)		
		Δ Y	Δ λ	Δ p	Δ Y	Δ λ	Δ p
Cooked, whole	8	—0.24	—0.2	—0.5	—0.45	0.0	—0.3
	16	—0.01	—0.5	—0.4	—0.51	0.2	—0.7
	24	—0.22	0.4	—0.8	—0.39	0.7	—1.1
	32	—0.43	0.2	0.4	—1.10	0.5	—1.0
	40	—0.21	0.6	—0.1	—0.88	0.9	—2.0
	55	0.11	0.3	—1.5	—1.04	1.2	—1.3
Cooked, blended	8	0.20	0.2	—0.3	—0.30	0.1	—0.9
	16	—0.30	—0.3	—0.4	—0.59	0.3	—0.8
	24	—0.37	0.4	—0.9	—0.93	0.7	—1.0
	32	—0.31	0.3	—0.7	—0.47	0.7	—1.4
	40	—0.87	0.4	—0.8	—0.92	0.9	—2.4
	55	—0.94	0.4	—1.2	—1.20	1.3	—1.9

measured by the spectrophotometer, this change has practically no visual significance, for according to Table 4 the total apparent color change is almost completely accounted for by the change in chromaticity. In other words, the perceptible color change is the graying and yellowing of the peas, with no significant change in lightness.

TABLE 4

Total Color Difference, Δ E, and Chromaticity Difference, Δ C (in Terms of NBS Units of Color Difference), Between Frozen Peas Stored at 0° F. and +10° F. as Compared with Peas Stored at −10° F.

Sample and form	Weeks' storage	(0° F.) − (−10° F.)		(+10° F.) − (−10° F.)	
		Δ C	Δ E	Δ C	Δ E
Cooked, whole	8	0.5	0.5	0.5	0.5
	16	1.8	1.9	0.5	1.6
	24	1.9	1.6	2.5	2.6
	32	0.9	1.1	3.2	3.4
	40	2.1	2.2	4.2	4.2
	55	2.4	2.4	5.9	5.9
Cooked, blended	8	0.3	0.3	0.5	0.6
	16	1.3	1.4	0.8	1.3
	24	1.2	1.3	2.8	2.9
	32	1.3	1.3	3.8	3.8
	40	1.4	1.6	3.9	4.0
	55	1.1	1.4	5.2	5.3

Comparison of Subjective and Objective Color Evaluation. In connection with the general quality appraisal of these peas *(9)*, judges made a visual appraisal of color. Under the observation conditions used the color difference between samples stored at 0° F. and −10° F. was not statistically significant at any period of storage up to the 40 weeks tested. The color difference between the 10° F. and −10° F. samples was significant from the twenty-fourth week on. In consideration of this result it would appear from Table 4 that color differences in peas viewed under the conditions of this experiment are not visually detectable until the differences are of the order of 2.5 to 3.0 NBS units. It is not surprising that color differences between samples of this nature, with such non-uniform surface and shadow areas between the peas, would be harder to detect than differences in uniform solid color plaques.

While the peas within a given lot were quite uniform in color when freshly processed, the changes apparent in the 10° F. samples occurred more rapidly in certain individual peas such that at the longer storage periods variability within a sample was quite evident. The approximate range of color in one lot stored at 10° F. for about one year is shown in Fgure 3. These curves

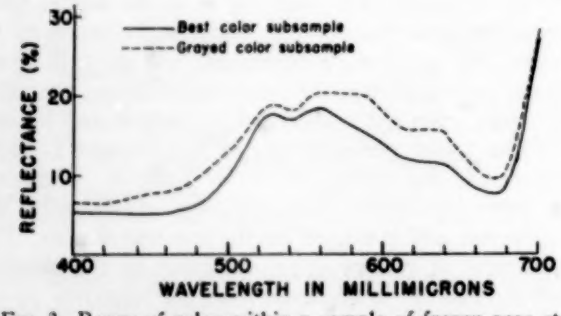

FIG. 3. Range of color within a sample of frozen peas stored at 10° F. for a period of one year.

were run on selected subsamples which represent the visual extremes of color. The differences in lightness ($\Delta Y = 2.69\%$), dominant wavelength ($\Delta\lambda = 2.7$ mμ), and purity ($\Delta p = 7.1\%$) are all much greater than the corresponding maximum overall changes observed (see Table 3). The apparent total color difference ($\Delta E =$ 12.5 NBS units) between these sub-samples indicates that it is possible changes in color are detected visually more readily by the variability of color that develops within a given sample than by an over-all color comparison of one sample with another.

CORN. COLOR CHANGES IN FROZEN CORN DUE TO MATURITY AND PROCESSING

Experimental Procedure. Objective color measurements have been made on samples of frozen whole-kernel sweet corn of two different varieties (Carmel Cross and Golden Cross Bantam) and of four maturities. Maturities were judged by moisture determinations on field samples and attempts were made to harvest at moisture levels of approximately 80, 75, 70, and 65 percent for samples of increasing maturity and designated 1, 2, 3, and 4 respectively in the tables below. Each variety and maturity was subjected to six processing procedures as follows:

A. Scalded on cob, water cooled, cut, shaker washed, frozen.
B. Scalded on cob, water cooled, cut, flumed 2 minutes, washed, frozen.
C. Kernels cut from cob, scalded, air cooled, washed, frozen.
D. Kernels cut from cob, scalded, water cooled, washed, frozen.
E. Kernels cut from cob, flumed 2 minutes, scalded, flumed 2 minutes, washed, frozen.
F. Partially scalded on cob, water cooled, cut kernels flumed 2 minutes, kernels scalded, flumed 2 minutes, washed, frozen.

Each sample was cooked and after a five-minute cooling period duplicate color measurements were made with the recording spectrophotometer and the reflectometer. Samples in whole kernel form were packed in 2 cm.-thick flat glass cells for measurement with the spectrophotometer, and packed flat in an aluminum tray (1 cm. deep) for measurement with the reflectometer. Color specifications and differences were calculated as described above.

In general, the differences in the reflecance spectrophotometric properties due to differences in maturity are similar in both varieties and are illustrated by the curves in Figure 4. As the maturity increases, the reflectance throughout the yellow-orange-red region increases, while the reflectance in the blue region decreases. The observed differences are indicated numerically in Table 5. The most apparent change is in chromaticity, the hue (or dominant wavelength) changing from a green yellow toward an orange yellow and the saturation (or purity) increasing as the maturity of the sample increases. These changes are apparent in Figure 5, which shows changes in chromaticity with maturity in the two different varieties of corn. This same trend of color difference is indicated by increasing "yellowness" in the reflectometer results.

No consistent trends of color change due to processing procedure were detected. Total color differences due to processing calculated from the reflectometer data are given in Table 6. The average color difference between the duplicate samples was 2.26 NBS units.

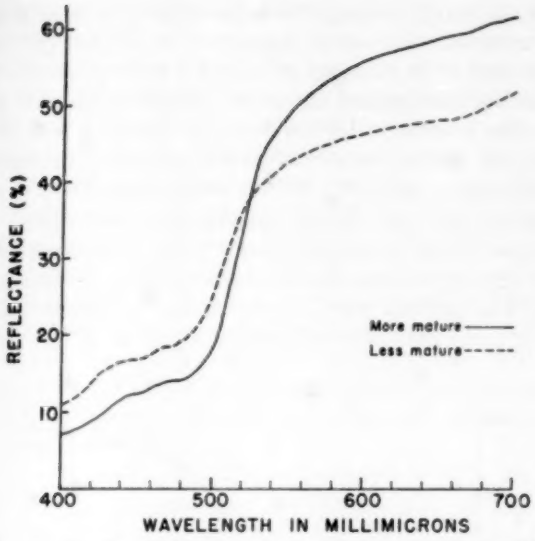

FIG. 4. Typical differences in the reflectance properties of frozen yellow sweet corn of different maturity.

Thus, while the color differences due to maturity are quite apparent (see Δ E, Table 5), relatively little significance can be attributed to the observed differences because of the processing procedures tested. It may be that some changes occurred in processes E and F, possibly due to the prolonged fluming of the cut kernels. (There is some evidence of a slight lightening of the color due to processes E and F.)

TABLE 5

Color Differences Due to Maturity in Frozen Yellow Sweet Corn

Variety	Maturity[d]	*Y*	λ	*p*	*Yns*	Δ E
Carmel Cross	1	0.410	575.7	45.0	0.732	....
	2	0.445	576.6	50.4	0.810	9
	3	0.462	577.5	61.4	0.920	20
	4	0.460	577.4	60.3	0.928	22
Golden Cross Bantam	1	0.440	576.7	54.7	0.860	....
	2	0.460	577.8	63.1	0.957	11
	3	0.454	578.3	64.5	0.981	13
	4	0.448	578.6	65.5	. 0.998	15

[d] For the definition of the stages of maturity, see text.

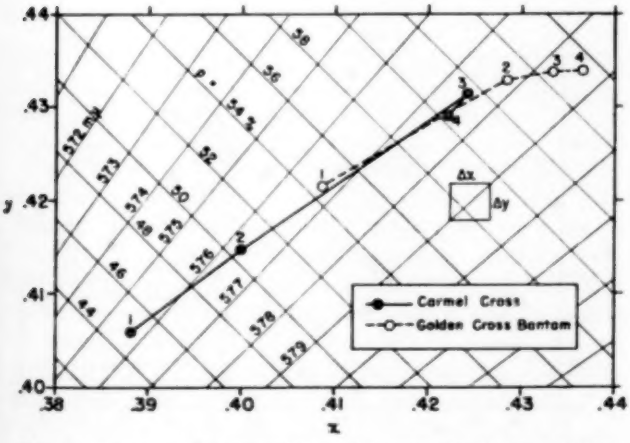

FIG. 5. Changes in chromaticity with maturity in two different varieties of yellow sweet corn. The points numbered 1, 2, 3, 4 represent increasing maturities in that order. (Spectrophotometer results on cooked, whole kernel samples.) Reproducibility is indicated by the average differences, Δ x and Δ y, between duplicate determinations on the samples.

TABLE 6

Color Differences (Δ E) Due to Processing Procedure with Process A Samples as Controls

Variety	Maturity [e]	Processing Procedure				
		B	C	D	E	F
Carmel Cross	1	....	4.9	....	....	....
	2	0.7	0.6	1.1	1.6	3.3
	3	2.1	1.4	2.1	3.5	1.9
	4	1.1	0.7	1.5	2.9	2.2
Golden Cross Bantam	1	1.2	1.8	1.3	....	4.3
	2	1.0	....	....	....	2.3
	3	1.8	0.8	1.8	2.6	2.7
	4	0.7	2.2	2.1	0.9	1.1

[e] For the definition of the stages of maturity, see text.

The significance and detectability of the observed differences can also be considered in terms of the Munsell notation. Although as yet we have no specific information on the subjective detectability of color differences in samples of surface character similar to kernel corn, it is reasonable to assume that differences will be at least no easier to detect than differences in uniform color samples. Under average conditions and for color differences of the order of significance for our purposes, the relation of the steps in the Munsell system is about: 1 value step = 2 chroma steps = 3 hue steps *(13)*. There is evidence *(3)* of a difference of one hue step in what has been called a "just easily noticeable difference." On this basis, just easily noticeable differences in the three color attributes are: 0.33 value step = 0.67 chroma step = 1 hue step.

Maximum differences for the corn in terms of the Munsell scales are listed in Table 7. In samples of a given variety and maturity, the maximum differences in hue and value due to processing procedure are, on the basis of the relation above, less than noticeable differences. Even though maximum differences in chroma are in some instances just noticeable, the average difference between samples in a given group is small enough that differences in color due to processing are probably not significant. A somewhat more than just noticeable difference in hue and three or four times a noticeable difference in chroma are apparent with differences in maturity.

TABLE 7

Color Differences in Frozen Yellow Sweet Corn with Differences in Maturity and Processing Procedure

Variety	Maturity [f]	Munsell Notation		Max. Difference Due to Processing		
		H	V/C	H	V	C
Carmel Cross	1	5.0	6.85/5.13	0.1	0.18	0.26
	2	4.5	7.10/5.82	0.3	0.16	0.86
	3	3.7	7.21/7.44	0.6	0.23	0.66
	4	3.7	7.20/7.27	0.3	0.16	0.60
	Max. Difference due to Maturity	1.3	.36/2.31			
Golden Cross Bantam	1	4.2	7.06/6.40	0.2	0.22	0.85
	2	3.4	7.20/7.70	0.1	0.10	0.33
	3	3.0	7.16/7.96	0.5	0.11	0.81
	4	2.7	7.12/8.10	0.5	0.11	0.28
	Max. Difference due to Maturity	1.5	.14/1.70			

[f] For the definition of the stages of maturity, see text.

CARROTS. COLOR CHANGES IN DEHYDRATED CARROTS WITH VARIATIONS IN PROCESSING, PACKAGING, AND STORAGE CONDITIONS

Experimental Procedure. In connection with a general study *(10)* of retention of quality factors in half-diced dehydrated carrots processed and stored in various ways, color changes have been observed and measured objectively in both dry and reconstituted, cooked samples. The samples consisted of lots as follows: (1) unblanched, (2) blanched only, (3) blanched and sulfited, and (4) blanched and sprayed with starch. For storage testing, lots were packaged in moisture resistant, transparent, anchor-coated, 450 gauge cellophane and tin containers, and stored at 84° F. (29° C.) for periods up to one year. Control samples were held under nitrogen in tin at —30° F. (—34° C.).

Satisfactory color measurements could be made with the reflectometer on dry samples packed flat in an aluminum tray (13 mm. deep) and viewed in a horizontal position in the instrument. No cover glass was used over the dry samples. Reconstituted, cooked samples were blended (5 parts sample to 8 parts water) and measured in the spectrophotometer with 1.5 cm.-thick flat glass cells and in the reflectometer with the flat aluminum tray (10 mm. deep) with a cover glass over the blended sample. Color specifications and color differences were calculated as described above.

The nature of the color changes in the dried material during the 12-month storage period is illustrated in Figure 6 by the reflectometer results. The bleaching or

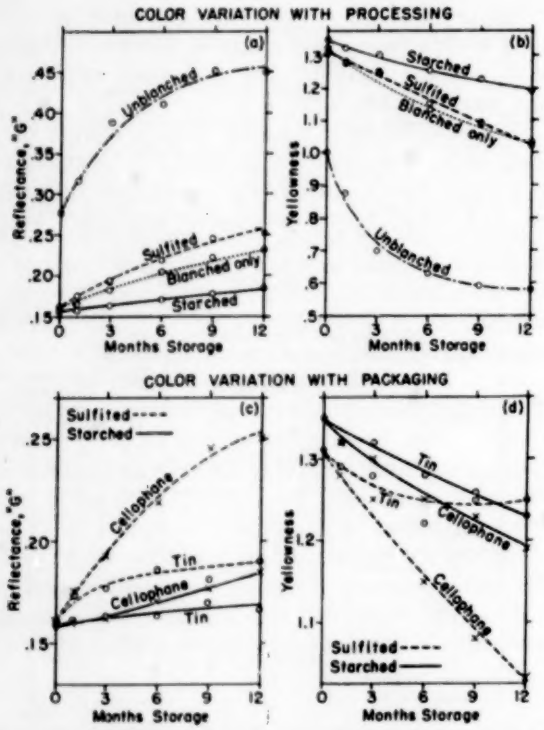

FIG. 6. Color changes occurring in dehydrated carrots during storage at 84° F. Graphs (a) and (b) indicate processing differences observed in cellophane packed samples, (c) and (d) indicate packaging differences observed in sulfited and starched samples. (Reflectometer results on dry samples.)

loss of color which occurred in all samples is shown by the increase in directional luminous reflectance, G, and the decrease in "yellowness," $(A-B)/G$. The latter index should perhaps be called "redness" in this instance since a natural red-orange carrot that becomes more yellow in color shows a decreasing index. The superiority of the starch coating over the other processes tested for retention of color is apparent in graphs (a) and (b) which show changes in G and Yns respectively for the cellophane-packed samples. Graphs (c) and (d) show the greater color retention in samples packed in sealed tin containers as compared with samples packed in cellophane, especially for the sulfited samples.

Essentially the same conclusions regarding the processing and packaging result from consideration of color measurements on the reconstituted, cooked samples. The general trend of the change in spectrophotometric properties is illustrated in Figure 7, which shows

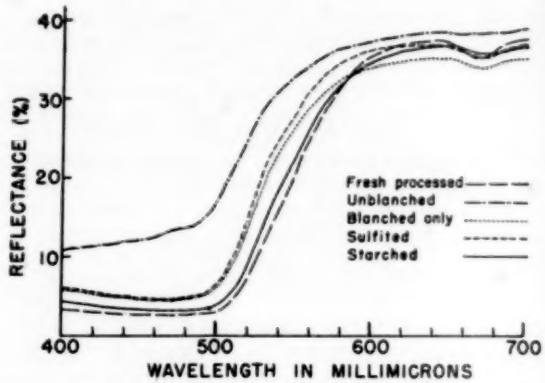

FIG. 7. Reflectance properties of variously treated dehydrated carrots after storage at 84° F. for 9 months in cellophane (reconstituted, cooked, blended samples). A curve for the freshly processed sulfited sample is included for comparison.

the curves from reconstituted, cooked, blended samples of the cellophane pack series after 9 month's storage compared with the "zero-storage-time" sample. Calculations from such curves show an increasing luminous reflectance, Y, and decreasing dominant wavelength, λ, and purity, p, with increasing storage time. The change in chromaticity with storage time for samples treated in the various ways is shown in Figure 8. The superior retention of color in the starch treated samples is apparent.

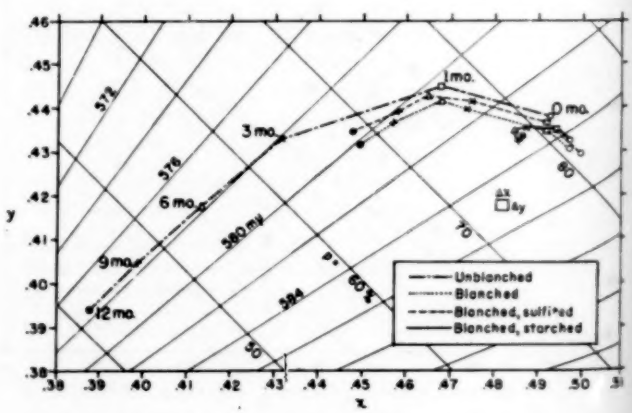

FIG. 8. Chromaticity change in dehydrated carrots stored in cellophane at 84° F. (Spectrophotometer results on reconstituted, cooked, blended samples.) Reproducibility is indicated by the standard deviations, Δ x and Δ y, determined from repeated measurements on samples stored at —30° F.

Visual Significance of Results. In order to clarify the significance of these observed color changes more directly in terms of what the eye sees, the color differences, Δ E, have been calculated from the reflectometer readings. The results in Figure 9 show the apparent total color changes during the storage period in the dry and cooked cellophane-pack samples. The freshly processed blanched, blanched-sulfited, and blanched-starched samples are very similar in color and the average of these "zero time" samples has been used as a control in calculating Δ E. The "zero time" unblanched sample is already quite noticeably different in color as seen in the figure. It is interesting to note that while the changes in the unblanched sample are more apparent in the dry material, changes in the other samples are more apparent in the cooked.

The relative noticeability of changes in lightness and chromaticity is illustrated in Figure 10. In the dry material, graphs (a) and (b), the changes in lightness and chromaticity are of approximately equal importance, while in the reconstituted, cooked material, graphs (c) and (d), differences in lightness are suppressed and the change in chromaticity becomes the predominant factor.

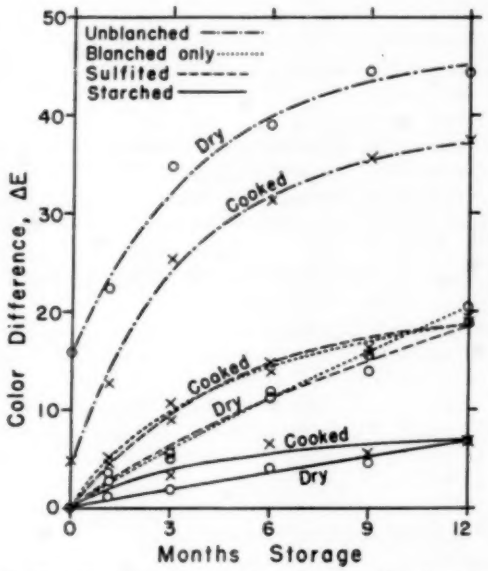

FIG. 9. Total apparent color changes occurring in dehydrated carrots during storage in cellophane at 84° F. (Reflectometer results on dry and cooked samples.)

Comparison of Visual and Instrumental Results. The color differences in the dry samples were also evaluated visually by judges at storage intervals up to 6 months. Samples were viewed under an artificial daylight illuminant and judges were asked to rate the various samples in comparison to the sulfited sample which had been stored in nitrogen at —30° F. Samples were rated from 7 to 1 according to whether they were, in the judge's opinion, similar to or differing to a less or greater degree from the control. The correlation coefficient for comparison of Δ E from reflectometer data and judges' color difference score, was $r = 0.96$ (slope = 0.26 = increase in judges' score for one unit change in Δ E, error of estimate = 0.58).

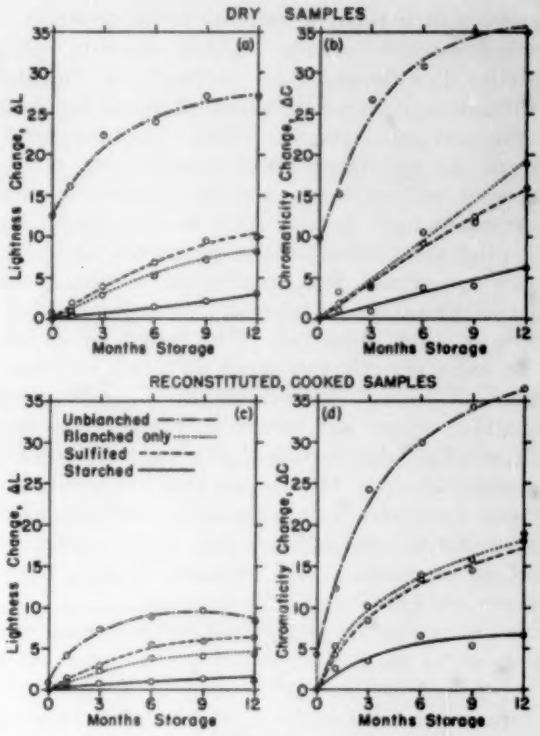

FIG. 10. Lightness and chromaticity changes in dehydrated carrots during storage. (Reflectometer results on dry and cooked samples.)

DISCUSSION AND SUMMARY

Objective measurements of physical properties related to the color of various food products have been made with a recording spectrophotometer and a multipurpose photoelectric reflectometer. The spectrophotometric curves and color indices calculated from them and the directional luminous reflectance and "yellowness" obtainable with the reflectometer serve to indicate the general nature of color differences and changes in foods due to processing and storage. Thus the following qualitative changes have been observed in foods tested:

(1) Peas held in the pod between picking and processing appear lighter and yellower than fresh peas.

(2) Frozen peas stored at +10° F. (—12° C.) became darker, yellower and grayer with storage time than peas stored at 0° F. (—18° C.) and —10° F. (—23° C.).

(3) As the maturity of yellow sweet corn increases, the hue changes from a green yellow toward an orange yellow and the saturation increases.

(4) Dehydrated carrots stored at 85° F. (30° C.) become lighter and the hue changes from red-orange toward yellow as storage time increases. Blanched, starch-treated samples show better retention of color than blanched-sulfited or only blanched samples, the latter two being about equal. Samples packed in tin show better color retention than samples packed in cellophane.

Quantitatively, for purposes of food appraisal, these observed changes and differences have been evaluated

in terms of their relative visibility to the observer. The spectrophotometer results, which measure physical properties directly and color indirectly by calculation, are difficult to interpret in terms of visual significance. For this and other reasons (size, complexity and expense of the apparatus, small sample area, etc.), the instrument will probably find its greatest application as a research tool. It will likely be very useful for investigating spectrophotometric properties and changes in these properties that may serve as the basis for design of simplified instruments for color control and grading in food industries. The reflectometer results can be more directly evaluated in terms of color differences of visual significance in a uniform-visual-detectability space. In fact a modification of the reflectometer has been developed *(8)* that reads such color differences directly. The success that has been achieved in these experiments in calculating differences from reflectometer results indicates that direct-reading color-difference instruments will probably be very useful in the study and grading of color in foods.

From the comparison of visual judgment and instrumental results on the temperature-series peas and from the reproducibility results on corn, it appears that for the type of material under test color differences must be of the order of 2 to 3 NBS (National Bureau of Standards) units to be significant. On this basis no visually significant color change was detected by the methods used in yellow sweet corn due to the freezing procedures tested, and significant differences in color of frozen peas were detected only after 24 to 32 weeks storage at +10° F. The methods used were adequate to detect visually significant differences in yellow sweet corn due to maturity (differences as high as 22 NBS units were observed) and in dehydrated carrots due to processing and packaging (differences as high as 44 NBS units were observed). In some instances (peas and corn) differences in luminous reflectance have been detected instrumentally which have little or no visual significance on the basis of lightness difference calculations.

Only general qualitative remarks can be made regarding possible correlation of color with other quality data collected *(9, 10)* on these products. In the dehydrated carrots, loss of color showed close agreement with loss of carotene, as might be expected, and also good agreement with loss of flavor as detected by trained taste panels. In the peas and corn, however, flavor changes were more apparent than color changes. Significant differences in the flavor of peas stored at 10° F. and −10° F. were detected after 8 weeks' storage, while color difference was not apparent until 24 or possibly 32 weeks' storage. Significant flavor differences were detected in the corn samples which could be attributed to processing procedure, especially to those processes which involved extensive fluming of the cut kernels, while essentially no significant color change due to processing was detected. Until considerably more data are obtained on the relation of color to general quality, it will have to be assumed that color is only one aspect of general quality, more or less independent of other physical, chemical, or nutritive qualities, and therefore color must be graded independently.

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